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## CIVIL ENGINEERING.

Translated for the Journal of the Franklin Institute.

*Examination of some Questions relative to Transportation.* By M. LAMARLE, Chief Engineer "des Ponts et Chaussées." Translated by J. BENNETT.

THE influence of the cost of transportation upon the products of industry, is now too well recognised to require comment. One of the chief causes of our inferiority in certain manufactures is due to the relative imperfection of our lines of communication; so that their development and improvement have been the constant object of the consideration and care of all the governments of the present century.

In this period, so fertile in improvements of this kind, a new fact of immense importance is produced; man, in this strife against distance, has fashioned an instrument of almost marvellous power, with a speed hitherto unknown, a nearly mathematical regularity, an unalterable constancy of service, and what was unexpected at the start, with a considerable economy in the cost of transportation. Such are the principal characteristics of this invention, which will remain in the history of material progress as the point of departure of a new era.

Thus railroads, notwithstanding the great capital they require, have rapidly multiplied; never has so costly an invention passed so largely and quickly into the domain of facts. Scarcely thirty years have passed since the meeting at Manchester, and more than 24,800 miles of roads in use have furrowed the soil of Europe, and over $200,000,000 have been devoted to the establishment of a net-work, which increases every

year. The united will of the people calls for new developments, whose limits cannot now be determined.*

This creation has notably changed the conditions of transportation; every year the railway draws to itself the most considerable masses of products, and is tending in a greater proportion to supply the places of the old traveled routes. In this respect it has exceeded the limits which could possibly be first assigned its influence, and its new action, scarcely foreseen and actively contested at an earlier date, but now certain and manifest, has raised questions of economy of great importance. We propose to investigate those which seem to have the most immediate interest.

2. The expense of transportation upon any route is divided into three principal parts:

1st. The interest of capital devoted to construction.
2d. The cost of maintenance.
3d. The expense of traction.

Sometimes capital is advanced by the State, the departments, and communes, without measures being taken to insure the payment of interest; this is the case with old roadways, which may course through all parts of the territory, and benefit the whole country. We need not specialize this part of the expense, which is merged in the general mass of taxes.

In other cases, the State procures by loans the funds required for effecting these new communications. It has then to provide for the payment of interest, and establishes tolls upon these lines, either to indemnify the amounts of their accounts, or for the payment of interest to the lenders. It is thus that the great canal system of 1821 has been executed.

Instead of loans, the government often grants to capitalists the right to make and collect determinate taxes for their remuneration. These grants are temporary or perpetual; in the first the company has to redeem the capital; in the second it is content with interest. A great number of canals and nearly all the railroads have been executed by concession, with or without subsidies from the public treasury.

The cost of maintenance of the way upon common roads is generally supported by taxes, with the exception of parish roads, where labor is called out to repair the wear and tear occasioned by the travel.

On navigable routes, the cost of maintenance as well as the interest of the first establishment should be covered by the tolls; only a portion of this expense, that of the use of the way, is sensibly proportional to the traffic, and would seem to be properly considered under the charge of traction.

This last, which constitutes the third element in the cost of transportation, is supported upon common roads and navigable routes by the commerce, which effects it with entire liberty. Upon railroads, on the other hand, the companies are held to operate all the transportation demanded of them, and receive in exchange a remunerating price.

* The lines conceded on the 31st December, 1857, amounted to 47,265 miles, of which 25,184 miles were open for travel.

Thus, they have to collect a tariff composed of two distinct parts: 1st, A *toll* representing the sum of general expenses, independent of the importance of the traffic; 2d, A tax upon transportation, corresponding with the expense of effecting it. The first part constitutes a public charge; it is an impost upon all merchandise, to liquidate the *constant* expenses of the enterprise; the second represents the reimbursement of expenses incurred by the company in the forwarding of merchandise; it varies with the development and conditions of circulation.

This in our opinion is an important distinction, and there will be occasion to refer to it.

3. We seek now to give an account of the value of these different elements, upon the different routes of communication.

For common roads, the cost of haulage, solely at the charge of trade, varies from 0·15 f. to 0·20 f.* per ton per kilometre (4·48 cts. to 5·98 cts. per ton per mile).

Upon navigable lines the taxes are quite various: all the navigable streams and rivers of the empire are subject to a toll of 0·0035 f. (0·104 cts.) per mile for first class merchandise, and 0·0015 f. (·045 cts.) per mile for second class. In the basins of the Aa and Escaut 0·005 f. is paid for the first class, and 0·002 f. for the second; upon other lines, the tolls, always referred to the ton and kilometre, varies from 0·01 f. to 0·109 f. (0·299 cts. to 3·27 cts.) per mile: the last tax, exceptional from its amount, answers to the Canal Saint-Denis, whose length is only 4·1 miles.

If we consider the somewhat extended navigable routes, as compared in this respect with competing railways, we have much less mean diverging results. In the following table are some which refer to the principal routes in the north of France:

| ROUTES. | Tolls. | Expense of Transportation. | TOTAL Per ton per kilo. | TOTAL Per ton per mile. |
|---|---|---|---|---|
| | fr. | fr | fr. | Cents. |
| From Mons to Paris, . . | 0 0117 | 0·0163 | 0·0280 | 0·8372 |
| " Charleroy to Paris, . | 0·0143 | 0·0173 | 0·0316 | 0·9448 |
| " Mons to Lille, . . | 0·0102 | 0·0214 | 0·0316 | 0·9448 |
| " Dunkirk to Lille, . | 0·0085 | 0·0187 | 0·0272 | 0·8133 |
| " Dunkirk to Cambria, . . | 0·0184 | 0·0208 | 0·0392 | 1·1721 |

The tariffs of railroads are uniform throughout France; they comprise four classes of merchandise, subject to the following taxes:

| CLASSES. | TAXES. Tolls. | Transportation. | Total. | Total per mile. |
|---|---|---|---|---|
| | fr. | fr. | fr. | cts. |
| 1st Class, . | 0·10 | 0 080 | 0·18 | 5·38 |
| 2d Class, . . | 0 09 | 0 070 | 0·16 | 4 76 |
| 3d Class, . | 0·08 | 0·060 | 0·14 | 4·18 |
| 4th Class, . . | 0·06 | 0·040 | 0 10 | 2·99 |

* Calling the franc 18·6 cts., multiply the francs per kilometre by 29·9 for its equivalent in cents per mile.

4. In comparing these prices, it would seem easy to form a clear idea of the distribution of circulation between the different routes passing between the same termini.

Railroads carrying at a cost of from 0·10 f. to 0·18 f. the ton, with a speed and regularity incomparably above that of common roads, must take preference, as the latter work at rates (0·15 f. to 0·20 f.) This is really the case, especially on long routes, where the advantage of the railway is more apparent.

As to navigable routes, less speedy and regular than the railroad, they present some economical advantages which should draw and retain all the heavy masses which without inconvenience can afford the delay. It would seem that they have only to lose the precious commodities, for which an increased price is preferable to the delays and damage incidental to long trips.

The facts at first sight would seem to confirm these previsions. If we examine the useful work accomplished by the navigation from 1850 to 1856, we find that it has not only not diminished, but has on the contrary increased nearly 33 per cent. in this period.

But if we discuss more carefully these results, if especially we take into account the development of traffic upon railroads, and the total increase of circulation, we arrive at very different consequences.

The following table gives a good view of this matter:

| DATES. | Work of 1000 tons carried one kil | | | Distribution between the two routes | |
|---|---|---|---|---|---|
| | Navigable Lines | Railroads | In all. | Navigation. | Railroads. |
| | m. t. k. | m. t. k. | m. t. k. | | |
| 1850 | 1722000 | 355000 | 2077000 | 0·82 | 0·18 |
| 1851 | 2164000 | 889000 | 30530·0 | 0 71 | 0·29 |
| 1852 | 2302000 | 1851007 | 4153007 | 0 55 | 0·45 |

We see from this table that the law of partition of traffic between the railroad and navigation has been greatly changed, to the prejudice of the latter. In 1850 it absorbed 82 per cent. of the carriage of bulky merchandise; in 1856 the proportion has been reduced to 55 per cent., hardly two-thirds. While the tonnage of navigation has thus increased only 33 per cent., in a progression whose ratio decreases each period, that of railroads has more than quintupled, with a velocity of increase yet in the ascendant.

Similar results have attended the transportation of Belgian oils to France. Here are some of the variations from 1852 to 1858:

| DATES. | Partition of transportation by | | Remarks. |
|---|---|---|---|
| | Navigation. | Railroads. | |
| 1852 | 0 92 | 0·08 | Documents presented to |
| 1854 | 0 80 | 0·20 | the Council General of |
| 1856 | 0 75 | 0 25 | the North 1858). |
| 1858 | 0 52 | 0 48 | First 6 months, 1858. |

Here the decline is still more clearly marked, and the prosperity of the railroad is much more rapid. This example is the more remarka-

ble, in that it applies to oil, the chief support of the Northern canals, and one of the commodities which might be regarded *à priori* unquestionably adapted to the navigable routes.

In presence of these facts, it is impossible to ignore the powerful influence of the railroad upon the merchandise of canals, and, however little we examine the law which governs these developments, we cannot but foresee the moment when the progress of traffic upon the canals shall be utterly checked, and when the decline, already apparent upon some of the lines, shall be progressively extended to the whole network.

5. These results, which seem anomalous in presence of official tariffs, are yet easily explained in taking account of two essential circumstances.

1st. The length of water-ways is always greater than that of competing railways; the excess, sometimes as high as one-half, is most generally between the third and quarter of the railway; it therefore increases the cost of transportation.

2d. This influence, though sensible, does not yet account for the observed fact. The cause of the marked preference of which the railroad is the daily object, is especially due to the great reductions in the official rate of their tariffs agreed upon by the companies. A single example enables us to appreciate its whole reach. From Quiévrain to Paris, a distance of 279 kilometres (173 miles), tariffed for oil, at the rate of 0·10 f. per ton per kilometre (2·99 cts. per mile), at 27·9 f., the Northern company reduced the total tax to 10·50 f.

This amounts to 0·0376 f. per ton per kilometre (1·12 cts. per mile), and occurs wherever the railway carries oil for long distances.

Such great reductions no longer admit the illusions of economists, who twelve years ago, fixed the lowest limit of railroad tariffs at from 6 to 7 centimes per kilometre (1·79 cts. to 2·09 cts. per mile); and in face of their assurances, we may expect to see the competition of the railroad much more widely extended; it is what every day's experience shows us.

6. But the railroad companies, not content with this so great latitude of variations, have introduced, in the application of reduced tariffs, other important modifications, in accordance with the quantities, distance, and conditions of the transportation; these changes have been applied so as to produce some singular anomalies: thus for short distances, the total charges have been sometimes greater than for long distances. The powerful industrial and great commercial interests have been specially favored, and the degree in which these companies have used the new tariffs, seems to constitute a formidable power upon all the industry of the country.

Thus most of the chambers of commerce, and a great number of the general councils, have been roused at the importance of these measures; and have united their voice with that of the canal interests, to protest against these *discriminating* tariffs.

The companies have usually defended their new tariffs, and their system has obtained the outside support of officials of undoubted abil-

ity.* The importance of this question, and the influence which its solution must exert upon the public welfare, impose upon us the duty of examining it carefully in its general bearing and its details.

The differential tariffs are presented under various forms. Most frequently, they accord reductions in price, according to the extent of travel; the price to pay per kilometre diminishes with the increased number of kilometres; this is the *differential* tariff proper.

Sometimes the companies reduce the price of transportation between two localities not traversed by the railroad direct, to what it would be if the route existed: these are called *indirect* tariffs, (tarifs de detournement.)

At other times they stipulate for reductions in favor of foreign products, and this is called the *international* tariff.

Sometimes merchandise obtains, by reason of its nature, great reductions by the *special* tariffs.

In private contracts, considerable abatements are accorded to forwarders, who engage to fulfil certain conditions, stipulated in the bargain, among which is generally found that of furnishing a minimum tonnage.

Finally (*les abonnements*) or allowance in favor of those industrial interests who renounce all other modes of transportation but the railroad.

7. With some unimportant exceptions, the fundamental principle which controls these tariffs is:

"To reduce the price of the unit of traffic in favor of those industrial and commercial interests who guarantee the company the greatest number of units: to increase the reductions in the ratio of the increase of these quantities."

This principle we must admit has been applied in most enterprises of land and water carriage; and these reductions can only be ascribed to the single element at their disposal, the expense of transportation which they operate in all freedom at their risk and peril.

This precedent, which affords the authority of a universal and constant practice, is otherwise fully justified. It cannot be denied that the directors of transportation derive a real economy in its expenses, from the fact of important commands, assuring long carriage, considerable masses, and a better distributed movement. It is quite natural, that in view of this economy, it should offer better conditions to the forwarders, who procure it, and so restore with an intelligent equity, a part of the advantages which they bring; undoubtedly this disposition specially applies to the great industrial and extended commercial interests, but it results from the very essence of things; it is no favor, but a practical recognition of an unquestioned fact, the economy always obtained in operating upon a great scale.

That the ancient administrations of transportation should have combined their tariffs, in this so rational order of ideas, and that it should be applicable outside of railroads, is easily justified. That the rail-

*The author here refers to a memoir of M. Ed. Boinvillers, member of state council. Without partaking of all his opinions, he pays tribute to the clearness of his views and the merit of his researches.

road companies should claim the same faculty is also easily understood; but what we can in no case admit, is that these *exceptional* reductions should ever surpass the value of economies realized, by reason of the most favorable conditions of the great industrial transportation. That there should be rendered to it, and it alone, all or part of the economies, which it alone furnishes the means of realizing, is well; but there in our opinion, the *differential* action of the tariff should be stopped. Thus these reductions of taxes should in our opinion apply exclusively to that part of the official tariff only which answers to the expense of transportation, upon which alone rests the economy of the net price.

When the reduction passing this limit, reaches the imposts of tolls, it should we think, *be common to all*, because in France, since 1789, equality of imposts existed for all. Surely, then, the small and the weak can rightly reclaim this protecting equality, this exact proportionality of tolls, the common basis of our financial system, and public rights.

| | |
|---|---|
| To explain our idea, we resume the example of the reduction allowed for the transportation of oil between Quévram and Paris, tariffed by their conditions at | 27·9 f. |
| To-day effected by the Northern Company at . . | 10·5 |
| Whence results a total reduction of . . | 17·4 |
| The conditions of contract fix the maximum rate of transportation at 0·04 f. per ton per kilometre, or for 279 kilometres, . . | 11·16 f. |
| On the other hand, it is known that in the best conditions possible, we cannot count upon an expense below 0·015 f. per ton per kilometre, or for 279 kilometres at least . . . . | 4·19 |
| The difference . . . | 6·97 |

Expresses then the maximum of possible economy upon the cost of transportation, by reason of the best conditions in mass, distance, and distribution. The total reduction of 17·40 f. accorded by the company, is composed then of two distinct parts:

| | |
|---|---|
| 1st. One, answering to the possible economy in the expense of transportation or the maximum as above, . . . . | 6·97 f. |
| 2d. The other, necessarily assignable to the tolls, equal at least to | 10·43 |
| Total reduction, . . . | 17·40 |

Here then the figure 6·97 f. represents, as we think, the *maximum of exceptional reductions* to be made in case of the most favorable conditions. The surplus constitutes, on the contrary, a part of the reduction necessarily assigned upon the tolls, upon *imposts*. In this respect the diminution it represents, should be extended to all transportations of the same nature, whatever may be their conditions. The small industrial departments should not be deprived of this reduction, without an injustice all the more to be regretted that it falls upon the most embarrassed part of the population.

The adoption of our opinion, would not in any case lead the railroad companies into operating at a loss, since they receive the integral of the taxes fixed for the expenses whenever the conditions of traffic may not afford any economy in this respect; they will thus be

repaid with the profit provided by contract for all expenses which they have incurred for transportation.

But if they judge best to effect new reductions upon the tolls, which do not correspond with any expense dependent upon traffic, they should we think be extended to all, because it is a veritable impost, which by its nature should be the same for all.

Far from opposing the differential tariffs as applied on account of the good market which they procure for certain freights, we reproach them, on the contrary, with rendering it relatively too dear for the majority of forwarders; what we contend against with all the energy of our conviction in the actual system, certainly is not the moderation of the taxes, but their elevation for the majority and the injustice which distributes the imposts of tolls precisely in the inverse ratio of the ability of those who have to pay them.

8. To prevent this injustice, and at the same time accounting to the great industrial interests for the economies which they alone have allowed them, it would suffice to determine in each particular case the value of reductions of expense resulting from the special conditions agreed upon for the freight, and to limit to this figure the maximum of *exceptional* advantages accorded to forwarders who accept them. Such should be the limit to assign to the differential elements of tariff.

Every reduction above this, falling then upon the tolls, should be made common for all freight of the same nature, whatever its importance, its production, and destination.

This rule, of an easy application, in its generality embraces, with the differential tariffs properly called the indirect tariffs, the international, special, and private bargains; but absolutely rejects the last class of tariffs or the tariff "d'abounement." In fact, the economy which such a condition procures for companies cannot be determined, since it cannot state precisely the quantity of merchandise assured to their traffic. Now to give the whole of its freight to the railroad, and obtain the same reduction, whatever the mass, is surely not to receive an equivalent for the economy it affords, but simply to receive a premium of the companies for uniting with them in the destruction of a rival interest.

(To be Continued.)

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*On Increased Brake Power for Stopping Railway Trains.* By Mr. ALEXANDER ALLEN, of Perth.

From Newton's London Journal, August, 1860.

The subject of increased brake power, for stopping quick trains in a shorter distance than is at present practicable, has become of great importance, and the attention of railway companies has recently been specially drawn to it by the railway department of the Board of Trade, by whom a number of experiments were tried on brakes of engines and carriages; and a recommendation was made to the railway companies for carrying out a system of continuous brakes to the whole train. The subject was also recently under the consideration of a committee

of the House of Commons, before whom evidence was given on the causes of railway accidents; this evidence was in favor of increased brake power on the engine, if not too suddenly applied; for it was shown that no brake on the carriages could be applied quickly enough to prevent accidents.

The subject of this paper is a plan for obtaining increased brake power, by retarding the speed of the engine by means of a throttle-valve placed in the exhaust-pipe, which can be instantly closed to any required extent, so as to obstruct the exit of steam from the cylinders, the regulator remaining open; at the same time the exhaust steam is admitted to a small cylinder, the piston of which acts through levers upon a brake on the engine wheels.

In this arrangement, the spindle of the throttle-valve projects through the side of the smoke-box, and is worked from the foot-plate by means of a lever and a connecting-rod. The brake cylinder is 8 to 10 inches diameter. The exhaust steam is admitted into the bottom of the cylinder through a $1\frac{1}{4}$ inch pipe, provided with a cock, and acting on the underside of the piston, lifts the brake lever and presses the brake blocks against the wheels. The cock in the $1\frac{1}{4}$ inch pipe is worked from the foot-plate, by means of a lever turning loose on the spindle of the throttle-valve; the throttle-valve can thus be closed, without at the same time admitting the exhaust steam to the brake cylinder, while the latter can also be instantly applied in cases of sudden emergency. When the steam pressure is removed from the cylinder, the weight of the piston and lever draws the brake blocks back clear of the wheels; the brake cylinder being contiguous to the smoke-box, and the pipe leading to it short and open to the heat in the exhaust pipe, there is no risk of water accumulating in the cylinder to prevent the descent of the piston when the steam pressure is removed. The brake blocks being under the charge of the engineman and fireman, will be regularly adjusted by them.

The brake cylinder applies the brakes simultaneously to the leading and trailing wheels of the engine, and the driving wheels are at the same time retarded by the back pressure of the exhaust steam on the pistons, consequent upon the closing of the throttle-valve in the exhaust pipe; the pressure of steam in the brake cylinder is the same as the back pressure in the driving cylinders, both being regulated by the extent of closing of the throttle-valve The power of the brake cylinder is limited, so as not to skid any of the wheels, in order to avoid wearing flat places on the tyres, and to produce the greatest effect in retarding the speed; a brake power of from 14 to 22 tons can thus be obtained by the steam brake alone. The brake power obtained by the use of the throttle-valve alone, retarding the driving-wheels of the engine, is equal to that of the tender brake, the regulator being open to the driving cylinders all the time. The application of the steam brake by the engineman may be followed immediately by that of the tender brake by the fireman, and the guard's brake in the van next to the tender; thus giving at once a greater brake power than has usually been applied in retarding trains, and diminishing the liability to accidents from want of sufficient brake power.

For the ordinary stoppages, the throttle-valve can be used to bring the train nearly to a stand, the tender brake being applied for the last few yards only; this will effect a great saving in the permanent way, tender, tyres and brake-blocks. By partially closing the throttle-valve, trains may be controlled to any desired speed in passing down an incline, while a great surplus of brake power is reserved in the steam brake cylinder, and the tender and van brakes, to bring the train to a stand quickly on the incline. In an experiment made with a gross load of 200 to 210 tons, down an average incline of 1 in 80, of 5 miles length, the train was controlled by the throttle-valve alone, from a speed of 30 miles per hour at starting, to 15 miles per hour down the whole incline. In approaching stations half the time may be saved by the joint use of the tender brake and the throttle-valve alone in the exhaust pipe, and a still further saving of time effected by also admitting the steam to the brake cylinder. By using the steam brake for ordinary purposes in place of the tender brake, there is less risk of heating and flattening the tyres, since the steam brake is so arranged as not to skid the wheels.

In this method of obtaining brake power from the engine, the speedy reversing of the engine valve gear from forward to backward gear is rendered an easy operation, whereby a further increase of retarding power is obtained; for the exhaust steam at the back of the driving pistons being compressed in the exhaust port by the closing of the throttle-valve, the pressure of steam inside the slide valves becomes equal to or greater than that outside in the steam chest, so that a balance of pressure is established, enabling the valves to be reversed instantly with perfect ease. The partial closing of the throttle-valve may be employed to prevent violent slipping of the driving wheels, which will revolve only in proportion to the quantity of steam allowed to escape from the exhaust pipe, and this may be regulated to any extent by the throttle-valve, which can be worked with greater ease and nicety than the regulator.

The retarding power of this steam brake was tested by the writer on the Scottish Central Railway. In the first two trials, only the throttle-valve in the exhaust-pipe was used, without the addition of the steam brake cylinder, thus retarding only the driving wheels of the engine by the back pressure of the exhaust; the third trial was made with an engine having the steam brake cylinder in addition to the throttle-vale.

From these experiments, it appeared that the retarding power produced by closing the throttle-valve in the exhaust pipe was fully equal to that of the tender brake; and the engine steam brake also produced an effect fully equal to the tender brake; so that, by employing both throttle-valve and steam brake in conjunction with the tender brake, the retarding power obtained was more than double that of the ordinary tender brake alone.

Mr. R. Morrison remarked, that he had seen some experiments upon a steep incline of 1 in 40 on the Edinburgh and Glasgow Railway, with a steam brake contrived by Mr. Paton, which gave a very power-

ful retarding force; the brake was applied to the leading and trailing wheels of a large tank engine having all the wheels coupled, and the pressure was produced by a steam cylinder communicating direct with the boiler. The action of the brake was very efficient, but he believed the principal objection to it was found to be the great shock caused by its sudden application, which often deranged the levers of the apparatus, and occasioned an objectionable concussion to the train.

Mr. Allen said that, with the plan of the throttle-valve in the exhaust-pipe, this objection was removed, as the pressure came on gradually by the gradual compression of the exhaust steam; and no objectionable shock was perceived beyond what was of course unavoidable in stopping a quick-moving train within a short distance: a train at a speed of 40 miles per hour was stopped in 150 yards upon a level, by means of the steam brake and tender brake, without any objectionable shock being produced.

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For the Journal of the Franklin Institute.

## *Repairs and Renewal of the Roche-Bernard Suspension Bridge.*

From a description given by M. Noyon, Engineer. Translated by J. Bennett.

### Part Second.

(Continued from page 156.)

*Correction of Camber of Platform.*—The platform, in obedience to all the movements of the primitive suspension bundles, must consequently rise in its middle 0·55 ft., and its camber, which at the mean temperature of 20° Centigrade (68° Fah.) stood at 4·26 ft., would attain 4·92 ft. at —5° (23° Fah.), and would occasionally be at 4·92 + 0·55 = 5·47 ft. Now, as the platform had too marked a rise in its primitive position, it seemed necessary to diminish the sagitta, so as to correct the effect of establishing the additional cable, as well as to remedy the inconvenience of the proximity of the cables and platform, with the chances of the yokes of the central part rubbing against the stringers of side-walks. It was accordingly reduced 0·88 ft.; so that the camber was never to exceed 4·59 ft.

To accomplish this, the suspension rods had all to be removed and their lengths changed. Some were shortened, others simply removed some rows towards the centre, and those lengthened which were to be hooked upon the new cables.

Advantage was taken of this circumstance in correcting a fault of 2·75 ins. of level which was found between the sides of the flooring. It would have been a long job by calculation, but a graphical method indicated in the *Annales des Ponts et Chaussées* (2d series, tome xx, p. 509) was used, whose correctness was fully confirmed in this new application.

During the removal and restoration of the rods thus corrected, the beams were suspended upon the cables by four strong tackles, two at each end, so that they could be raised and freed from the stirrups and

the rods removed. This operation was effected symmetrically on each side, and to avoid confusion on the removal of the rod, care was taken to substitute in the number of its order another number corresponding with a table, giving the changes to be definitely assigned them.

*Replacing the Rods.*—The placing of the rods borne by the primitive cables was easily effected; not so, however, with those suspended from additional cable; for there was much difficulty in bringing the latter to its final position, not only from their great distance from the old cable, but from the successive derangements it experienced in proportion as its extremities were loaded. Attempts were made to bring them together by powerful screws and rope lashings, but only a few of the rods near the porches could be placed by this means, and to secure a good position for the placing of the others, the platform had to be suspended to the supplementary cable; the rods were furnished with lengthening pieces, which were successively shortened and suppressed when the cables were sufficiently close.

The difficulties were greater, since the lowering of the supplementary cable was only 1·47 ft. instead of 1·80 ft. as supposed; the difference is due to not accounting for the friction of the supplementary cables upon the sheetings of the old cables; for it is evident that an isolated wire, such as was used, moves more freely than a layer composed of 1400 wires with a width of 31·50 ins. and a thickness of from 1·4 to 2 ins.

Though this result was not unexpected it seemed prudent not to depart from the figures, which had been arrived at by two different means; the error, if it was one, seemed to incur less inconvenience than might have followed from the increased sagitta. Too great a distance between the cables would have appeared badly, while it was feared that too great a lowering of the supplementary cable would have prevented its bearing all the load reserved for it and cause much difficulty in preparing the rods.

*Actual Rise of the Platform.*—The platform actually rose 0·46 ft. Consequently, the summit of the new cables must have descended under the load $1·80 - (0·46 + 0·33) = 1·01$ ft.

*Establishment of the Counter-cables. Their Position and Form.*—Each counter-cable described between the points of attachment, and in a plane inclined 77° to the horizon, a curve, which, supposed to be plane, was nearly a parabola with a chord of 207·78 yards and a rise of 8·75 yards. It was composed of 600 No. 19 wires, forming a cylindrical bundle 4·33 ins. diameter.

*Mooring Anchors.*—Four wrought iron anchors 4·33 ins. square, being bent at right angles, embrace the masonry of the porches and are countersunk in the same, thus constituting the mooring system of the counter-cables.

The branches perpendicular to the axis of the bridge enter 5·25 ft. the piers of the arcades next the tower, and are connected two and two upon each bank by two strong bars of iron 2·75 ins. square with an eye at their ends, through which passes a dowel 2·36 ins. diameter, passing also through the anchors. The latter have a development

of 32·75 ft. and weigh each 2238 lbs. They were forged and puddled with great care at Rive-de-Gier, in the foundries of MM. Jackson, Petin, Gaudet & Co.

*Rods and Suspension Stirrups.*—The counter-cables (Plate III, Fig. 3) are suspended from suspension beams by round iron rods 1 inch diameter, with a hook at one end and an eye at the other, through which passes a reversed iron stirrup of the same dimensions whose branches and cross-piece are arranged so as to embrace exactly the end of the beam.

In the middle of the bridge this mode is impracticable on account of the small space between the bottom of the flooring and top of counter-cable; the latter is therefore connected with the 21 central beams by a system of bridles shown in Plate III, Fig. 4.

The branches of these bridles, as well as those of all the stirrups, have a worm 4·3 ins. long, by which the counter-cable can be raised or lowered.

The stirrups, as well as the double bridles, abut against the inner faces of the outer stringers and are hid beneath sidewalks.

*Fabrication of Counter-cables.*—They were made on site of bridge, but in an inverse order from definitive position.

Upon each head of bridge a standard wire, whose length was deduced from the rise and chord of the final curve, was stretched in the direction A E C (Plate III, Fig. 1) between the mooring anchors, and served as an indicator for placing all the wires in the corresponding cable.

A carrier, starting from the point Q upon right bank, unrols the wire, one of whose ends have been attached to the anchor C and passes from Q to R, always having the roll at arms length and outside of suspension rods. On coming near the left bank, at R, he stops a moment to give the workmen upon the scaffolding $v'$ $u'$ time to draw the unrolled wire towards them, to hook it upon end of anchor A, and to return the end; he then returns towards Q, while with the windlass T the portion A K C of the wire is stretched so as to coincide with the regulating wire A E C; it is held in this position by an iron vice. Performing the same operation, by means of the windlass T, upon the wire passing from R to Q, a second element of the cable is obtained, and so on to the end; only the different wires once in place serve as standards for all that are to come upon them.

An agent placed upon the small foot-bridge $z$ $s$ suspended under the bridge and in the line of its transverse axis, watched for the coincidence of the wires among themselves or with the standard, and by signs from him those in charge of the winches T and T′ were guided in increasing or diminishing the tensions of the wires.

Each wire in its passage from one bank to the other was sustained by small bars projecting from the ends of the beams, and when its ends were hung upon the two anchors, it was dropped in the position A K C (Plate III, Fig. 1).

As the wires were put in place they were formed into bundles of 50 strands; these bundles were successively united by temporary liga-

tures. Without this precaution the wind would have impressed them with a continual motion, making it difficult to regulate the others.

The transfer of the wires from one bank to the other was effected upon the bridge itself, thus compelling the holding of the rolls at arms length, and the unrolling to be made beyond the suspension rods.

This was a troublesome condition and delayed the work; otherwise there would have been required foot-bridges upon each side of the platform and outside of the railing, or workmen would have to be posted upon the summits of the porches and raise the wires by hand.

These arrangements, besides being expensive, would be attended with risk, and it was thought best to take more time than to needlessly expose the lives of the workmen.

*Cost of putting up the Counter-cables.*—The two counter-cables were made in 22 days of effective work, with a force of 20 men: 6 cablers, 12 workmen, an assistant, and an agent specially charged with regulation of wires.

At the rate of $9·20 per day, the total cost was $22 \times 9·20 = \$202·40$; which is 16·8 cents per wire, or ·54 cents per lb. This is but half the price generally given to master cablers for making and putting up by contract the common cables of suspension bridges.

*Ligatures of the Counter-cables.*—Before making the ligatures of the counter-cables, they are to be suspended from the platform of the bridge. For that purpose they were seized at sixteen points by strong tackles attached to the old cables; then, having raised them to the proper height, they were held by twenty-one rods distributed along the whole span.

In this position the counter-cables are sufficiently stiff to receive the small scaffolding (Plate III, Fig. 5) upon which are placed the workmen in charge of the ligatures.

This scaffolding, formed of a large plank with two (*i k*) hooks in front and two cords upon the back, which secured it both upon the counter-cable and upon two of the bridge beams, was very solid and easily managed.

The cablers employed upon the ligatures were also provided with a safety girdle, the cord *u* of which was attached, on each station, to the hand-railing *l* of the bridge.

*Oiling the Wires.*—The workmen to whom this duty was intrusted traveled horse-back fashion from the summit to the ends of the cable, upon a kind of saddle with stirrups which they themselves could slide. All were provided with a safety belt, whose cord was held by a workman upon the bridge who accompanied them throughout.

*Mastic of Cables.*—In a similar manner the mastic of the cables was laid on; only this part of the work was deferred till the suspension rods had been definitely placed.

*Effects of Change of Temperature on the System of Cables.*—As has been said, the counter-cables are designed to oppose the vertical motions produced by the wind, and their efficacy is due solely to the solidity existing between them and the other cables. This solidity seemed to present a serious inconvenience, resulting from the contrac-

tions due to the lowering of temperature. So that before executing this part of the work prescribed for the consolidation of the bridge, it was proper to consider the amount of inconvenience and to study some mode of remedying it while adhering to the disposition ordered by the administration.

The solution of this question depending upon the influence really exerted by changes of weather upon the wires united in bundles, for clearing up this matter numerous observations were made at different times, both upon the Saint Christopher bridge, near Lorient, and upon the Roche-Bernard.

It is generally admitted that the amount of elongation or contraction of an iron rod for 1° Centigrade is 0·0000122 ft. per foot, or for 1° Fah., 0·00000677 ft. per foot; but this is on the supposition that the action is of sufficient duration to be imparted to the different molecules of the metal. Now this condition is not fulfilled in the cables of suspension bridges: first, because from the daily changes in temperature the effects are transitory, and even in those hours when the temperature is stationary the different elements of the cables are not equally sensitive when grouped in bundles of from 4 to 7 ins. diameter, separated from each other as they are by fat unguents, painting, mastic, &c., all poor conductors of heat.

It was important to know the difference between the results of calculation and the data of observation.

To obtain the actual expansion of the cables, the sagitta of the parabolic bundles of the above named bridges were measured directly at different temperatures, and from the excess of each above the smallest was deduced the corresponding elongation of the cables by the following considerations.

According to Navier (Memoire sur les ponts suspendus, 2d edition, p. 139) the depression of the bridge flooring, resulting from a small increase $\gamma$ in the half length $h$ of the the cables, is given (the primitive sagitta being equal to $f$) by the relation

$$\varphi = \frac{3h}{4f}\gamma, \tag{1}$$

which may be written under the form

$$\gamma = \frac{4f}{3h}\varphi. \tag{2}$$

On the other hand, as the weight of the flooring holds the cables constantly stretched in all parts, whatever the temperature, the elongation produced by heat in the retaining bundles R M, N T (Plate III, Fig. 6), must be nearly entirely added to that arising from the expansion of the suspension bundles.

Consequently, if we place successively in the formula (2) instead of $\varphi$ the increased lengths of the sagitta $f$, the values of $\gamma$ will approximately represent the real expansions of the portion R M S of cables by their corresponding changes of temperature.

In this way the numbers in the 6th column of the table B were calculated in making $f = 48{\cdot}42$ ft. and $h = 317{\cdot}58$ ft. for the Roche-

Bernard bridge, and $f = 45{\cdot}73$ ft. and $h = 298{\cdot}22$ ft. for the Lorient.

The figures of column 7 are deduced from the relation

$$\gamma' = 0{\cdot}0000122 \text{ L } t \qquad \text{(metrical units)},$$
$$\text{or} \quad \gamma' = 0{\cdot}00000677 \text{ L } t \qquad \text{(units of feet)},$$

in which $t$ represents the difference between the height of thermometer at the time of measurement of any sagitta and that indicated at the smallest of them, and L the development of the portion R M S of cables, which was 574·14 ft. or 475·71 ft., according as the formula was applied to the one or the other of the bridges.

A comparison of columns 7 and 8 shows that the ratio between the real and calculated expansions is 0·58 for the Saint Christophe and 0·78 for the Roche-Bernard bridge. Consequently, in dealing with analogous metallic bundles of suspension bridges, the co-efficient of expansion should be reduced

$$0{\cdot}00000677 \times 0{\cdot}78 = 0{\cdot}00000528 \qquad \text{(units of feet)}.$$

The disagreement for some of the observations between the variations of sagittæ and those of thermometer, is due solely to the inequality of temperature in the cables and air. We have also, from a comparison of the columns 3 and 5, for the mean expansion or contraction of the sagitta, for each degree of heat or cold,

0·007 m. for Roche-Bernard, or 0·0127 ft. 1° Fah.
and 0·005 m. for Saint Christophe, or 0·0091 ft. "

This being the case, let us consider a common suspension cable M S N (Plate III, Fig. 6) and a counter-cable A C B connected by rigid rods, and the latter to have been laid at a time when the temperature was $t°$. If the temperature increases, the bundle M S N will lengthen, and the middle of the flooring and the summit C of the counter-cable will fall a length equal to that which S has fallen. Moreover, the counter-cable also expanding will have less tension than at the time of its laying, and the small catenaries which it describes between the suspension rods will take a greater sagitta; but this circumstance has but a secondary interest and we need not dwell upon it.

When, on the contrary, the temperature lowers, the two cables which, were they independent of each other, would contract and take the respective positions M S′ N, A C′ B, lengthen in virtue of their extensibility, so that the distance of their summits remains nearly the same and the effects of contraction are thus compensated. From this arises a new tension, P, which is always relatively much greater for the counter-cable, whose section is generally less than that of suspension cable. To determine this tension, we will suppose that for an instant the latter is not counteracted in its movements, and that the counter-cable only yields, and elongates the necessary quantity for the summit of the cable M S N to be freely transported from S to S′.

Designating by $f$ and $f'$, $\omega$ and $\omega'$, the respective sagittæ and sections of the cable and counter-cable; by $2\,l$ the development of the first, and by $2\,l'$ that of the second, and by $h$ the half span, we have, for a falling of temperature of $t°$, a contraction of the suspension cable

expressed by $2\,l\,a\,t$ ($a$ being the real co-efficient of expansion), to which corresponds (formula 1) a contraction from the initial sagitta:

$$\varphi = \frac{3\,h}{4\,f}\,l\,a\,t;$$

for the counter-cable, the contraction of the sagitta from this same falling of temperature will be

$$\varphi' = \frac{3\,h}{4\,f'}\,l'\,a\,t.$$

Consequently, if the counter-cable alone supports the tension P, its sagitta will have an increase equal to

$$\varphi + \varphi' = \tfrac{3}{4}\,h\,a\,t\left(\frac{l}{f} + \frac{l'}{f'}\right).$$

And therefore its length will be increased (formula 2) by the quantity

$$2\gamma = 2\,\frac{4\,f'}{3\,h} \times \tfrac{3}{4}\,h\,a\,t\left(\frac{l}{f} + \frac{l'}{f'}\right) = 2\,a\,t\left(\frac{f\,l}{f'} + l'\right).$$

Now the force P′ necessary to elongate an iron bar of the length $2\,l'$ by the quantity $2\gamma$ is given by the relation

$$\text{(3)} \qquad P' = \frac{E\,\omega'}{2\,l'}\,2\gamma;$$

$\omega'$ being the section of the bar expressed in square feet, and E the co-efficient of elasticity, which is supposed equal 22000 kilogrammes per square millimetre, or 4507552379 lbs. per square foot.

Consequently, the effort experienced by the counter-cable has for its expression

$$\text{(4)} \qquad P' = \frac{E\,\omega'}{2\,l'}\,2\,a\,t\left(\frac{f'\,l}{f} + l'\right) = E\,\omega'\left(1 + \frac{f'\,l}{f\,l'}\right)a\,t.$$

This quantity P′ is evidently a superior limit of the tension P; for by reason of the solidity existing between the counter-cable and the suspension cable, the latter experiences this same tension, and its summit, instead of rising to the point S′, stops a little below at S″, for example; so that in reality the counter-cable is only elongated by the quantity $2\gamma$ diminished by the increased length $2\gamma'$ which would be produced in the suspension cable by the application of the force P.

In truth, this increase is not known, but its value may be nearly obtained when it is considered as differing but little from that which the force P′ found above would determine in the entire suspension cable; for then the extension of the wire due to this force being equal (formulæ 3 and 4) to

$$2\gamma' = \frac{2\,P'\,l}{E\,\omega} = 2\,\frac{l\,\omega'}{\omega}\left(1 + \frac{f'\,l}{f\,l'}\right)a\,t,$$

we have (formula 1), for the corresponding increase in the sagitta of the curve,

$$\varphi'' = \frac{3\,f\,l\,\omega'}{4\,h\,\omega}\left(1 + \frac{f'\,l}{f\,l'}\right)a\,t.$$

* In original $2\,E\,\omega$; not correct.

Consequently, the increase in the sagitta of the counter-cable would be reduced to

$$(\varphi + \varphi') - \varphi'' = \tfrac{3}{4} h a t \left[\frac{l}{f} + \frac{l'}{f'} - \frac{l\omega'}{f\omega}\left(1 + \frac{fl}{fl'}\right)\right].$$

To this variation of sagitta answers an extension of the counter-cable inferior to $2\gamma$ and equal (formula 2) to

$$2\gamma'' = 2at\left[\frac{f'l}{f} + l' - \frac{f'l\omega'}{f\omega}\left(1 + \frac{f'l}{fl'}\right)\right].$$

But this may be considered as produced by a force $P''$ having for expression

$$P'' = \frac{E\omega'}{2l'} 2\gamma'' = Eat\omega'\left[\frac{f'l}{fl'} + 1 - \frac{f'l\omega'}{fl'\omega}\left(1 + \frac{f'l}{fl'}\right)\right]$$

$$= Eat\omega'\left[\left(1 + \frac{f'l}{fl'}\right)\left(1 - \frac{f'l\omega'}{fl'\omega}\right)\right].$$

Now this quantity is an inferior limit of the tension sought, P, and, consequently, the mean, $\frac{P' + \rho''}{2}$, may be regarded as a near approach to the value of this tension.

To apply these formulæ to the Roche-Bernard bridge, we suppose

$$f = 48{\cdot}55 \text{ ft.}, f' = 24{\cdot}93 \text{ ft.}, l = 574{\cdot}14 \text{ ft.}, l' = 313{\cdot}31 \text{ ft.},$$
$$\omega = 0{\cdot}41034 \text{ sq. ft., and } \omega' = 0{\cdot}0586 \text{ sq. ft.}$$

Moreover, according to the results of observations upon the expansion of cables, we should give to the co-efficient $a$ the value 0·00000528 instead of 0·00000677, admitting 45° (Fah.) as the lowest range of the thermometer below that of the day when the standard wire was set, for the making of counter-cable we have

$$P' = 121768 \text{ lbs., and } P'' = 105447 \text{ lbs.,}$$

whence $$P = \frac{P' + \rho''}{2} = 113607 \text{ lbs.}$$

The absolute force P represents an increase of tension of 1921 lbs. per sq. in. for suspension cable, and 13460 lbs. for the lower cable.

From this it appears there is no need of being concerned for the action of the counter-cable upon the system of suspension properly called, while it is important to reduce as much as possible the inverse effect, so that no cause may intervene at a given moment to diminish the force of the counter-cable against violent shocks transmitted by the platform when agitated by the wind.

*Means of preventing the effect of changes of Temperature upon the counter-cable.*—The most simple method of obviating this inconvenience would evidently be to increase the normal length of counter-cable by a small quantity, $\rho$, such that, even in the lowest temperatures, it may contract without difficulty, permitting the suspension cable to move as if it were free.

This small increase in length distributed uniformly over the curve would not impair the rigidity, and will suffice to compensate the occa-

sional contractions from the lowering of temperature. Thus the counter-cable, instead of taking the position A C′ B, will be drawn from A C B to A C″ B by the suspension cable, even when the latter has attained its extreme position M S″ N; and all the points of one will rise an equal quantity with the corresponding points of the other.

In fact, the summit C, in its removal to C″, allows the summit S to be displaced an equal quantity $S\,S'' = C\,C'' = \phi$ in the same direction; and as the tensions developed during these movements in the two parabolas M S N and A C B are distributed nearly uniformly upon the horizontal $U\,V = 2\,h$, the curves M S″ N and A C″ B may be regarded also as parabolas.

But the equations of the lines M S N and M S″ N referred to the coordinates O X and O Y, and in regard to the previously adopted notations being respectively

$$y = \frac{f}{h^2}x^2 + O\,S$$

and

$$y = \frac{f-\phi}{h^2}x^2 + \phi\,O\,S.$$

The difference $b\,b' = d$ of their corresponding ordinates $a\,b$ and $a\,b'$ is found equal to

$$d = \frac{f-\phi}{h^2}x^2 + \phi - \frac{f}{h^2}x^2 = \phi\left(1 - \frac{x^2}{h^2}\right).$$

This expression, in which the constants $\phi$ and $h$ only enter, shows that for the two other parabolæ A C B and A C″ B, whose summits are the same distance, $\phi$, apart, the difference of the ordinates will be deduced from a similar formula.

*Definitive Sagitta of Counter-cables.*—It was natural to adopt the means just indicated; and as the counter-cables were made at their site by means of a standard wire which was established at a temperature of 20° (68° Fah.); and as in this locality the cold was never below 23° Fah., the normal length $l$ of the wire was increased by a quantity $\rho$ equal to the sum of the contractions $\rho'$ and $\rho''$, which would be experienced by suspension cables for a lowering of 45° Fah. of temperature.

Now the value of $\rho'$ is given by the table B (26 observation) and is equal to $2 \times 0{\cdot}124$ ft. $= 0{\cdot}248$ ft.,

that of $\rho''$ is deduced from the relation:

$$\rho'' = l\,a\,t = 626{\cdot}62 \times {\cdot}00000518 \times 45 = 1{\cdot}48 \text{ ft.},$$

and therefore $\rho = \rho' + \rho'' = 0{\cdot}396$ ft.

From the increased length, $\rho$, assigned to the standard wire was deduced the sagitta to be given it, that of the counter-cable having been fixed at 24·93 ft. for a temperature 68° Fah.

The general formula (1), in which we supposed

$$h = \frac{623{\cdot}35}{2} = 311{\cdot}67 \text{ ft. and } \gamma = \frac{\rho}{2} = 0{\cdot}198 \text{ ft.},$$

gives the increase of sagitta $\phi$, corresponding to the excess of length

ρ to be given the regulating wire, and so its definitive sagitta was equal to

$$24{\cdot}93 + 1{\cdot}83 = 26{\cdot}76 \text{ ft.}$$

*Effect produced by change of length of Counter-cables.*—It was thought that the small excess in length given to the counter-cable, would not sensibly change the figure of equilibrium, and that distributed over a development of 626 ft. it would not diminish the rigidity of the system. But this was not the case; the cable, when projected upon a vertical plane passing through longitudinal axis of bridge, followed a regular and continuous curve, but seen aside, the curve was changed, and each of the semi-arcs A C and C B assumed an inflected form, like a flat and elongated S.

This disagreeable effect was due to the marked double curvature necessarily taken from their inclination to the horizon and the excess of length it had been thought proper to give it. So serious an imperfection was not admissible, and care was taken to correct it.

For this purpose the primitive form of the cable was changed and the haunches were raised towards the platform, not only to absorb the excess of length, but to compensate by a small exaggeration of the curve of the central part of each semi-arc the appearances produced in an inverse direction, which otherwise would not have disappeared, since the double curvature is inevitable whatever may be the tension.

This change was effected by trials and by the simple displacement of the counter-cable rods, which were moved back 1, 2, or 3 rows towards the mooring points of the latter.

In these conditions the counter-cable, it is true, must more sensibly feel the effects of a lowering of temperature; but the strain arising from the momentary contraction in its length and that of the suspension cables will never exceed 21 lbs.; and as it will then be found very rigid, and so more effectively opposed to the vertical motions of the platform, there is no fear that this strain will be much increased by the present slight oscillations of the suspended system.

*Conclusions.*—The three prescribed operations of the administration have yielded the most satisfactory results.

The new galleries are effectually guarded against moisture and filtering water; they are well ventilated, easy of access, of suitable dimensions, and the mooring bundles are so arranged as to be easily maintained in all parts.

The establishment of the counter-cable has produced a remarkable stability in the system.

The vertical oscillations, whose amplitudes attained from 12 to 23½ ins. in high winds and 39 ins. in gales, are to-day insignificant. The greatest observed since the laying of the cable were below ¾-in.

The diligence drawn by three horses at a gallop produces a scarcely appreciable effect; it is the same with ten mounted horses at a smart trot, or the march of thirty men.

The horizontal swinging of the platform is completely checked, and the permanent convexity of about 10 ins., which it formerly presented on the up-stream side, has wholly disappeared.

The presence of the supplementary and counter-cables have in no-

wise impaired the lightness, elegance, and harmony of the general construction.

A few observations are selected from the thirty referred to by the author, and given in the following table B, showing the changes in length of sagittæ of cables by the variations of temperature for Roche-Bernard bridge.

| Order of observations. | Dates of observations. | Temperature in degrees. | | Sagittæ observed. | Real variation of sagittæ | Variations in half length of cables | | Observation. |
|---|---|---|---|---|---|---|---|---|
| | | Cent. | Fah. | | | deduced from those of sagittæ. | deduced from changes of temperature. | |
| | | ° | ° | m. | mm. | mm. | mm. | |
| 1 | Dec. 27, 1856, | + 2 | 36 | 14·81 | 0·050 | 0·010 | 0·013 | *b* |
| 3 | " 31, " | 0 | 32 | 14·795 | 0·030 | 0·006 | 0·009 | |
| 5 | Jan. 13, 1857, | + 6 | 43 | 14·820 | 0·060 | 0·012 | 0·021 | |
| 10 | " 29, " | — 4 | 25 | 14·800 | 0·040 | 0·008 | 0·002 | |
| 12 | Feb. 6, " | — 5 | 23 | 14·760 | 0·000 | 0·000 | 0·000 | |
| 14 | " 18, " | + 4 | 39 | 14·825 | 0·065 | 0·013 | 0·017 | |
| 17 | Mar. 7, " | — 1 | 30 | 14·805 | 0·045 | 0·009 | 0·008 | |
| 18 | " 11, " | + 6 | 43 | 14·820 | 0·060 | 0·012 | 0·021 | |
| 21 | May 4, " | +14 | 57 | 14·965 | 0·205 | 0·042 | 0·036 | |
| 23 | " 16, " | +20 | 68 | 14·97 | 0·210 | 0·042 | 0·047 | |
| 25 | July 14, " | +31 | 88 | 14·980 | 0·220 | 0·045 | 0·068 | |
| 28 | Aug. 12, " | +43 | 109 | 15·04 | 0·280 | 0·057 | 0·091 | |
| Totals | | 468 *a* | | | 3·405* | 0·689* | 0·885* | |

*a* This number represents the sum of variations referred to the point of departure — 5°.

*b* The variations in length start from the lowest observed sagitta 14·76 m.; and those of temperature are referred to — 5° of thermometer.

* These are sums averages of the 30 observations.

CORRECTION.—In the March number, page 155, line 9,

$$\left(1 + \frac{2\,f^2}{2\,h^2}\right) \text{ should be } \left(1 + \frac{2\,f^2}{3\,h^2}\right).$$

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*Observations on the Niagara Railway Suspension-Bridge.* By P. W. BARLOW, C. E., F. R. S., &c.

From the London Builder, No. 927.

One of the most remarkable results from Mr. Barlow's personal and careful examination of the Niagara Railway Suspension-bridge is, that the favorable conclusions to which that examination has led, induced him to suggest the formation of two cross lines of suspension railway over the central districts of London, one commencing at the Elephant and Castle, and terminating near the Shoreditch station of the Eastern Counties Railway; and the other commencing at the junction of Oxford-street and Tottenham-court-road, and terminating at Whitechapel. Street-railways, he suggests, might converge from the outskirts to these lines. The cost of a wire suspension-girder viaduct, with a span of 1000 feet, would not, he estimates, exceed, for a double line of street omnibus traffic, £150,000 per mile. The only land re-

quired would be for the wrought iron towers, as a wire-bridge might be erected without the least interference with the intermediate property. Allowing £100,000 per acre (the average cost of the terminus of the South-Eastern Railway) for the land required, or £50,000 per mile, the whole scheme might, he calculates, be carried out for a little above £1,000,000. He further suggests the adoption of wire suspension-bridges where bridges have been long projected and abandoned from their cost and interference with property as hitherto proposed; and as an example he suggests the connexion of Holborn and Newgate-street by a suspension-bridge, thus avoiding Holborn-hill. A wire suspension-bridge, with towers of wrought iron, constructed like a vertical lattice beam, he urges, would offer little obstruction to the light, and would not exceed in cost the sum of £75,000. Mr. Barlow also proposes to connect Liverpool with Birkenhead by a wire suspension-bridge, 150 feet above the level of the river, at an estimated cost of £1,000,000, passengers to be raised to the level of the bridge at one end and lowered at the other by steam power. The span of this bridge would be no less than 3000 feet. He also proposes to suspend a similar bridge from New York to Brooklyn, with a span of 2000 feet.

The Niagara bridge, notwithstanding certain defects, Mr. Barlow is convinced, "is the safest and most durable railway bridge of large span which has been constructed:—first, because it is less liable to deterioration; and secondly, because the greatest strain to which it can be submitted is a less proportion of the ultimate strength of the supporting material."

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### *Steam Navigation on Canals.*

From the Journal of the Society of Arts, No. 422.

It is stated that the Grand Junction Canal Company have brought into use steam power for canal navigation, which if successful will materially reduce the cost of conveyance. The peculiar feature in the steamboats employed to ply between London and Birmingham or Manchester is a form of screw propeller, invented by Mr. Burch of Macclesfield. This "waggle tail" propeller is said to have the advantage of keeping all the disturbance of the water immediately behind the stern of the boat, instead of spreading it right and left, thus securing the canal banks from being damaged by the wash, and economizing the motive power. On Tuesday, the 18th inst., a party of gentlemen accompanied Mr. James Fulton, one of the company's officers, in a trip from the City Basin along the Regent's Canal to Paddington, a distance of five miles and three quarters, which was accomplished in an hour and a half, including the passage of five locks, and the Islington tunnel, half a mile long. The *Pioneer*, an ordinary fly-boat, 75 feet long by 7 feet extreme breadth, 25 tons burden, and drawing 2½ feet of water, with an engine of six-horse power, was the boat employed, towing another fly-boat which was laden with a general cargo to go to Wolverhampton. The two boats were able to go through the locks at once, floating side by side, and thus saving much delay. It is stated

that the *Pioneer*, when tried at Manchester, proved able to draw six loaded barges at once, with a total burden of no less than 300 tons. Four miles an hour, allowing for the locks and other hindrances, it is estimated will be the average rate of steam performance, instead of two miles an hour, the usual speed obtained by horse-towing. The steam-boat has stowage room for 2½ tons of coal, which will carry her from London to Birmingham and half-way back, superseding the expensive relays of horses and drivers requisite for so long a journey. This water locomotive is estimated to be nearly 30 per cent. cheaper than railway carriage.

It may be observed that the aggregate amount of canal traffic, instead of diminishing, has increased since the construction of railways, and is now 25,000 tons more than it previously was. The total length of canals now open in Great Britain is about 5000 miles, including all the branch lines and junctions, and these works represent a capital of some forty millions.

## MECHANICS, PHYSICS, AND CHEMISTRY.

### *On the Chemical Constitution of Cast Iron and Steel.* By M. E. FREMY.

From the Lond. Chemical News, No. 49.

The interesting communication of Captain Caron* has furnished me with the occasion to make known to the Academy some of the results obtained in a research—which I have long pursued—into the constitution of cast iron and steel. The facts here stated have been already communicated to several Members of the Academy, and I have likewise alluded to them in my lectures at the Polytechnic School.

Numerous observations prove that nitrogen exercises an influence over the phenomenon of steeling, and confirms the opinion which our learned colleague, M. Despretz, has recorded in his work on Nitride of Iron.

Indeed, all chemists are aware of the rapid transformation of iron into steel under the influence of ferro-cyanide of potassium, and the interesting researches of M. Sanderson, in which this skilful manufacturer proves that in the cementation boxes steel is formed only under the double influence of carbon and nitrogen. I considered that in the process of cementation, the nitrogen not only presented the carbon in a gaseous state to the iron, but that, remaining united to the carbon, it could itself combine with the metal.

The presence of nitrogen in certain specimens of iron, cast iron, and steel, has been already recorded in the most precise manner by M. Marchand. It remained to discover under what state nitrogen could exist in steel or cast iron. This is the question I desire to examine.

In following the method of Berzelius, when steel or cast iron is submitted to the action of bi-chloride of copper, a residue containing graphite and a brown matter is obtained. This last substance is not

*Chemical News, Vol. II, p. 243.

carbon, as is generally believed; it is partly soluble in potash. When heated, it disengages a considerable quantity of ammonia, and shows an analogy with certain derivatives of cyanogen. Experiments (which I shall make known in a special Memoir) tend to prove that cast iron and steel, hitherto considered as carbides of iron, are rather combinations of metal with a compound radical, comparable to cyanogen, and which, like it, is produced directly by combination of carbon with atmospheric nitrogen. The brown matter before alluded to, and the empyreumatic oil formed during the action of acids on cast iron and steel, will be the products of the decomposition of this compound radical.

The metalloids, such as sulphur, phosphorus, and arsenic, which modify so remarkably the properties of steel and cast iron, act, in my opinion, principally on the nitrogen compound of which I have just spoken, and can even modify it by substitution. On this point I shall adduce an experiment which appears to me interesting in a theoretical point of view, and which explains some facts observed in practice.

A specimen of cast iron, rich in graphite, prepared with wood charcoal, was melted in the middle of a siliceous slag. The ingot thus obtained was covered with graphite, and the casting, charged during the operation with three per cent. of silicium, remained grey and malleable. It consequently resembled the grey cast iron prepared with coke under favorable conditions. Silicium was substituted in this case for carbon, which, crystallizing to the state of graphite in the metallic mass, formed the grey siliceous cast iron so well known to metallurgists. The same grey cast iron was then submitted to the action of various slags, so as to impart sulphur, phosphorus, or arsenic to the metal. In these trials, the cast iron became white, and the metalloids were substituted for the carbon, which being completely eliminated from the metallic bath, crystallized on the surface into large plates of graphite. These specimens of cast iron treated by acids, produced the empyreumatic oils which contained the metalloids employed to whiten the cast iron.

When sulphur is introduced into cast iron, it expels a part of the carbon, and forms a sulphuretted radical, producing a white cast iron no longer possessing the property of incorporating itself with graphite, like the ordinary grey cast iron.

By studying the modifications produced by metalloids on the organic substance contained in cast iron, fine metal, and steel, the relation between these products is determined. For this purpose, the existing chemical analyses are inadequate; indeed, the analytical notions bearing upon the crude determination of carbon contained in cast iron and steel, furnish no useful indication, for, in general, the name of carbon is given to a mixture of graphite and an organic nitrogenous substance; account is also taken of the graphite, which is simply interposed in the metallic mass, and plays no part whatever, while the determination of the nitrogenous substance, which appears to be the really active body, is neglected.

Upon the whole, it appears to me at the present time impossible to

admit that cast iron, fine metal, and steel, are formed essentially by the combination of iron with carbon, and that the difference between them is due simply to the proportion of this metalloid present. The substance which in the preceding compounds modifies the properties of iron so usefully for the arts, may be sometimes a metalloid, and also sometimes a compound; it is then allied to the derivatives of cyanogen, and, like them, is transformed by the action of metalloids; when this substance contains either nitrogen, sulphur, phosphorus, or arsenic, it forms, when united with iron, cast iron, either white, or grey and spotted, fine metal, and steel.

The color and appearance of the castings are not sufficient, then, to determine their composition; there are several kinds of white castings, which differ from one another according to the nature of the metalloid they contain; a grey casting, prepared with coke holding two or three per cent. of silicium, may resemble another grey specimen prepared with wood, which is scarcely siliceous. The relations which connect cast iron and steel are not so simple as is generally believed.

At a period when it is required to produce steel at a low price, and various methods are in operation for converting cast iron into steel, it appears to me that the preceding facts may guide iron-masters in their experiments, especially in determining the nature of the problem to be solved.—*Comptes-Rendus.*

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*Density of Absolute Alcohol, and its Mixtures with Water. Correction.*

In our Journal for 1860 (3d ser. vol. XI, p. 268), we published the table of results of M. Baumhauer upon the specific gravities of alcohol and its mixtures, together with his assertion that his numbers were totally different from those of Lowitz and Gay-Lussac. It now appears that in this assertion, M. Baumhauer was totally mistaken; and that when all the conditions of the experiments are taken into consideration, his numbers furnish a very remarkable confirmation of those of Gay-Lussac and of Gilpin; the greatest difference between Gay-Lussac and himself being 0·0003; the mean of 16 sets of experiments, 0·00014; between Gilpin and Baumhauer, maximum difference = 0·0006; mean difference of 18 sets of experiments = 0·00016. This result will give great additional confidence in our usual tables, which are founded on the experiments of Gay-Lussac and Gilpin.

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*Silver Test.*

Silver coins, jewelry, or any other rich alloy, when moistened with a solution of chromic acid, or a mixture of bi-chromate of potassa and sulphuric acid, become covered with a red-purple spot of bi-chromate of silver. This spot does not occur on poor alloys or metals imitating silver.—*Cosmos*, September, 1860.

For the Journal of the Franklin Institute.

*Strength of Materials:* Deduced from the latest experiments of Barlow, Buchanan, Fairbairn, Hodgkinson, Stephenson, Major Wade, U. S. Ordnance Corps, and others. By CHAS. H. HASWELL, Civil and Marine Engineer.

No. 6.

(Continued from page 192.)

## CRUSHING STRENGTH.

The Crushing Strength of any body is in proportion to the area of its section, and inversely as its height.

Experiments upon cast iron bars, give a crushing stress of 5000 lbs. per square inch of section, as just sufficient to overcome the elasticity of the metal, and when the height exceeds three times the diameter, the iron yields by bending.

When the height of a prism or column is not 5 times its side or diameter, the crushing strength is at its maximum.

| | | | | |
|---|---|---|---|---|
| When it is | 10 | times it is reduced as | 1·75 | to 1. |
| | 15 | " | 2· | to 1. |
| | 20 | " | 3· | to 1. |
| | 30 | " | 4· | to 1. |
| | 40 | " | 6· | to 1. |

In tapered columns, the strength is determined by the least diameter.

The experiments of Mr. Hodgkinson have determined,—

The resistance to fracture from flexure in long columns of like dimensions, is about three times greater when the ends of the columns are flat and firmly bedded, than when they are rounded and capable of being diverted from their vertical position.

An increase of strength of about $\frac{1}{4}$th to $\frac{1}{8}$th of the breaking weight is obtained by enlarging the diameter of a column in its middle.

In cast iron columns of the same thickness, the strength is inversely proportional to the 1·7 power of the length, nearly. Thus, In solid columns, the ends being flat, the strength is as $\frac{d^{3\cdot6}}{l^{1\cdot7}}$, *l representing the length*, and *d*, *the diameter.*

In hollow columns having a greater diameter at one end than the other, or in the middle than at the ends, it was not found that any additional strength was obtained over that of uniform cylindrical columns.

The strength of a column in the form of that of a connecting rod of an engine, was found to be very low: being less than half the strength that the same metal would have given if cast in the form of a uniform hollow cylinder. The ratio being as 175 to 396.

The strength of a column irregularly set, the pressure being in the direction of its diagonal, is reduced to one-third of its strength when the pressure is vertical.

In rectangular columns, the length and quality of the material being the same, the square gives the highest strength.

With cast iron, a pressure beyond 12 tons per square inch is of little if any use, in practice.

For equal decrements of length, wrought iron will sustain double the pressure of cast iron.

Glass and the hardest stones have a crushing strength from seven to nine times greater than tensile; *hence*, an approximate value of their crushing strength may be obtained from their tensile and contrariwise.

A hollow column of cast iron, 10 inches in diameter, and but $\frac{3}{4}$ inch thick, may be extended to 12·5 feet in height, and possess the same resistance as a solid column of like weight, 6·5 inches in diameter, and but 7·5 feet in height.

TABLE OF THE CRUSHING STRENGTH OF VARIOUS MATERIALS.

Deduced from the Experiments of Major Wade, Hodgkinson, and Capt. Meigs, U.S.A., and reduced to an uniform measure of

*One Square Inch.*

| FIGURES AND MATERIAL. | Side or diameter. | Height. | Crushing weight. |
|---|---|---|---|
| CAST IRON PRISMS. | Ins. | Ins. | lbs. |
| American, gun metal | ·6 | 1·5 | 147,803 |
| mean | ·6 | 1·5 | 129,000 |
| English, Low Moor, No. 1 | 1· | 1· | 62,450 |
| do do | 1·25 | 2· | 63,640 |
| do No. 2 | ·75 | 1·5 | 92,330 |
| Clyde, No. 3 | ·75 | 1·5 | 106,039 |
| Calder No. 3 | ·75 | 1·5 | 101,000 |
| Stirling* No. 2 | ·75 | 1·5 | 119,550 |
| Mean of all, | ·75 | 1·5 | 122.395 |
| Extreme, | 1· | 1·5 | 134,400 |
| WROUGHT IRON PRISMS. | | | |
| American, mean | 1· | 1· | 83,500 |
| English, | 1· | 1·875 | 65,200 |
| METAL PRISMS. | | | |
| Fine Brass, | 1· | 1· | 164,800 |
| Cast Copper, | 1· | 1· | 117,000 |
| Wrought do., | 1· | 1· | 103,000 |
| Cast Tin, | 1· | 1· | 15,500 |
| Lead, | 1· | 1· | 7,730 |
| CAST STEEL. | | | |
| Soft, | | | 198,944 |
| Tempered, | | | 373,041 |
| do. mean | | | 295,000 |
| Tungsten, | | | 155,916 |

*Cast and Wrought Iron mixed.

| Wrought Iron. | Width. | Thickness. | Area. | |
|---|---|---|---|---|
| Plates. | Ins. | Ins. | Ins. | |
| Length, 10 feet, | 2·98 | ·497 | 1·48 | 815 |
| 10 " | 3·01 | ·766 | 2·30 | 3,379 |
| 7 " 6 inches, | 1·02 | 1·025 | 1·05 | 9,752 |
| 5 " | 1·02 | 1·024 | 1·05 | 17,267 |
| 2 " 6 " | 1·02 | 1·024 | 1·05 | 25,327 |
| 1 " 3 " | 1·02 | 1·023 | 1·05 | 34,555 |
| Hollow Cylinders. | External. | Internal. | | |
| Length, 9 feet 11 inches, | 1·495 | 1·292 | ·444 | 14,661 |
| 9 " 11 " | 2·49 | 2·275 | ·804 | 29,779 |
| 10 | 2·34 | 1·91 | 1·435 | 22,179 |
| 10 | 6·366 | 6·106 | 2·547 | 35,886 |
| Rectangular Tubes. | | | | |
| Length, 10 feet, lap riveted, | 4·1 | 4·1 | ·504 | 10,980 |
| 10 " lap riveted, | 4·1 | 4·1 | 1·020 | 19,261 |
| 10 " lap riveted, | 4·25 | 4·25 | 2·395 | 21,585 |
| 10 " lap riveted, | 8·4 | 4·25 | 6·890 | 29,981 |
| 10 " lap riveted, | 8·1 | 8·1 | 2·070 | 132,76 |
| 10 " lap riveted, and with two internal diaphragm plates, | 8·1 | 8·1 | 3·551 | 19,800 |

| Cast Iron. | Diameter. | Height. | Crushing weight. |
|---|---|---|---|
| Solid Cylinders. | Ins. | Ins. | lbs. |
| English, Low Moor, No. 3, Dry sand, | ·5 | 60·5 | 730 |
| " " Dry sand, | 1· | 60·5 | 2,423 |
| " " Dry sand, | 1·96 | 60·5 | 8,097 |
| " " Green sand, | ·5 | 60·5 | 2,485 |
| " " Green sand, | 1· | 60·5 | 8,061 |
| " " Green sand, | ·51 | 20·16 | 1,914 |
| " " Green sand, | ·5 | 12·1 | 3,595 |
| " " Green sand, | ·52 | 2· | 11,433 |
| " " Green sand, | ·52 | 1· | 12,308 |
| Hollow Cylinders. | External diameter. | Internal diameter. | |
| English, Low Moor, No. 3. Height, 7 feet 6·75 inches. Dry sand, | 1·75 | 1·21 | 31,298 |
| | 1·99 | 1·31 | 39,804 |
| | 2·23 | 1·54 | 58,796 |
| Woods. | Diameter. | Height. | |
| Oak, American | 1 | 1 | 4,100 |
| Canadian | 1 | 2 | 5,982 |
| English | 1 | 2 | 9,500 / 6,484 |
| Yellow Pine, | 1 | 2 | 5,375 |
| Ash, | 1 | 2 | 8,663 |
| Beech, | 1 | 2 | 9,363 |
| Cedar, | 1 | 2 | 5,768 |
| Elm, | 1 | 2 | 10,331 |
| Box, | 1 | 2 | 9,265 |

| Material. | Diameter. | Height. | Crushing weight. |
|---|---|---|---|
| Woods (Continued). | Ins. | Ins. | lbs. |
| Mahogany, Spanish | 1 | 2 | 8,198 |
| Sycamore, | 1 | 2 | 7,082 |
| Walnut, | 1 | 2 | 6,645 |
| Teak, | | | 12,100 |
| Stones, &c. | | | |
| Granite, Patapsco | 1 | 1 | 11,200 |
| Sandstone, Aquia Creek* | 1 | 1 | 5,340 |
| Seneca† | 1 | 1 | 10,764 |
| Aquia Creek, strata laid horizontally, | 1 | 1 | 8,332 |
| Marble, Stockbridge‡ | 1 | 1 | 10,382 |
| East Chester§ | 1 | 1 | 23,917 |
| Symington, large crystals,‖ | 1 | 1 | 11,156 |
| Same, strata horizontal, | 1 | 1 | 10,124 |
| Same, strata vertical, | 1 | 1 | 9,124 |
| Same, fine crystal, | 1 | 1 | 18,248 |
| Italian | 1 | 1 | 12,624 |
| Lee, Mass., | 1 | 1 | 22,702 |
| Hastings, N. Y., | 1 | 1 | 18,941 |
| Montgomery co., Penna., | 1 | 1 | 8,950 |
| Baltimore, large crystal, | 1 | 1 | 8,057 |
| do small crystal, | 1 | 1 | 18.061 |
| Freestone, Belleville | 1 | 1 | 3,522 |
| Connecticut | 1 | 1 | 3,319 |
| Dorchester | 1 | 1 | 3,059 |
| Little Falls | 1 | 1 | 2,991 |
| Caen | 1 | 1 | 1,088 |
| Gneiss, | 1 | 1 | 19,680 |
| Brick, hard | 1 | 1 | { 4,368<br>{ 2,000 |
| Common | 1 | 1 | { 4,000<br>{ 800 |
| English Craigleith Limestone, | 1 | 1 | 5,600 |
| " Sandstone, | 1 | 1 | 31,449 |
| Arbroath, | 1 | 1 | 7,884 |
| Stone, | 1 | 1 | 8,270 |
| Caithness, | 1 | 1 | 6,493 |
| Portland, | 1 | 1 | { 15,583<br>{ 4,570 |
| Aberdeen granite, | 1 | 1 | { 8,400<br>{ 10,363 |
| Portland oolite, | 1 | 1 | 3,850 |
| Limestone, | 1 | 1 | 3,065 |
| Portland cement, mean, | 1 | 1 | 8,300 |
| Adelaide Sandstone, | 1 | 1 | 2,800 |
| Sydney " | 1 | 1 | 2,228 |
| Normandy Caen, | 1 | 1 | 1,543 |
| Portland Cement 1, Sand 2, | 1 | 1 | 8,400 |
| " 1, " 3, | 1 | 1 | 5,000 |
| " 1, " 4, | 1 | 1 | 5,900 |
| " 1, " 6, | 1 | 1 | 8,400 |
| Fire Brick, English, | 1 | 1 | 2,442 |
| " Stourbridge, | 1 | 1 | 1,717 |
| Stock " | 1 | 1 | 2,177 |
| Red " | 1 | 1 | 807 |
| Marble, | 1 | 1 | 6,431 |

* Same as that of the Capitol, Treasury Department, and Patent Office, Washington, D. C.
† " Smithsonian Institute. ‡ Same as that of the City Hall, New York.
§ " General Post Office, Washington. ‖ " National Wash. Monum't.

COMPARATIVE STRENGTH OF CAST AND WROUGHT IRON TO BEAR COMPRESSION IN THE DIRECTION OF THEIR LENGTH.

Dimensions of Bar, 1 inch square, and 10 feet in length.

*Decrease in Length.*

| Weight. | Cast Iron. | Wrought Iron. | Weight. | Cast Iron. | Wrought Iron. |
|---|---|---|---|---|---|
| lbs. | Ins. | Ins. | lbs. | Ins. | Ins. |
| 5,054 | ·054 | ·028 | 27,498 | ·300 | ·143 |
| 9,578 | ·102 | ·052 | 29,738 | | ·151 |
| 11,818 | ·126 | | 31,978 | ·357 | ·174 |
| 14,058 | ·151 | ·073 | 40,938 | ·503 | |
| 23,018 | ·247 | ·119 | 54,378 | ·865 | |

RESISTANCE OF CAST AND WROUGHT IRON BARS TO COMPRESSION, LAID VERTICALLY.

*One Inch Square, and Ten Feet in Length, enclosed in an iron frame to maintain them in a vertical position.*

CAST IRON.

| Iron. | Weight applied. | Extension. | Set. |
|---|---|---|---|
| | lbs. | Ins. | Ins. |
| Low Moor, No. 2, . . | 2,100 | ·0230 | ·00100 |
| | 4,200 | ·0442 | ·00325 |
| | 8,401 | ·0884 | ·00862 |
| | 16,802 | ·1773 | ·02125 |
| | 33,604 | ·3810 | ·07262 |
| Blaenarvon, No. 2, . | 2,032 | ·0191 | |
| | 4,064 | ·0391 | ·00187 |
| | 8,125 | ·0791 | ·00483 |
| | 16,257 | ·1618 | ·01775 |
| | 32,514 | ·3439 | ·06270 |
| Mean of four kinds, . . | 2,064 | ·0187 | ·00047 |
| | 4,129 | ·0388 | ·00226 |
| | 8,258 | ·0788 | ·00645 |
| | 16,517 | ·1634 | ·01712 |
| | 33,030 | ·3534 | ·06096 |

WROUGHT IRON.

*Ultimate Practical Resistance.*

Mean weight, 26,933 lbs. Mean compression, ·139 inches.

*Hence*, the length of the bars being 10 feet = 120 inches, $\frac{120}{\cdot 139} = 863$; consequently, a wrought iron bar will bear a compression of $\frac{1}{863}$ of its length, without its utility being destroyed, although its elasticity will be materially injured.

*To Ascertain the Crushing Strength of a Solid Cylindrical Column of Cast Iron.*

$\frac{d^{3\cdot6}}{l^{1\cdot7}} \times 100000 = \text{w}$. *d representing the diameter of the column in inches. l, its length in feet, and* w *the crushing weight.*

EXAMPLE.—What is the resistance to crushing of a solid cylinder, 2 inches in diameter and 5 ft. in length?

$$\frac{2^{3\cdot6}}{5^{1\cdot7}} = \frac{12\cdot125}{15\cdot426} \times 100000 = 78601 \text{ lbs.}$$

*To Ascertain the Crushing Strength of a Hollow Cylindrical Column of Cast Iron.*

$\frac{D^{3\cdot6} - d^{3\cdot6}}{l^{1\cdot7}} \times 100000 = W.$ D *representing the greater diameter.*

EXAMPLE.—What is the resistance to crushing of a hollow cylindrical column having diameters of 2 and 1·25 inches and a length of 7 feet?

$$\frac{2^{3\cdot6} - 1\cdot25^{3\cdot6}}{7^{1\cdot7}} = \frac{12\cdot125 - 2\cdot233}{27\cdot332} \text{ which, } \times 100000 = 36190.$$

The above formulæ are those of Hodgkinson for the breaking or crushing weight. The formulæ of Euler, which are for the incipient breaking weight, are preferable and are with the alteration of the coefficient, thus: $\frac{d^4}{l^2} \times 100000 = W$ for solid cylinders, and $\frac{D^4 - d^4}{l^2} \times 100000 = W$ for hollow cylinders.

The safe load that may be borne by a column of cast iron, independent of any considerations, regarding the operation of its ends as to their being square or not, or flat, or rounded, &c., is from 5000 to 8000 lbs. per square inch for short or stable bodies.

NOTE.—The above formulæ apply to all columns where the length is not less than about 30 times the external diameter; for columns shorter than this, a modification of the formulæ is necessary, as in shorter columns the breaking weight is a large portion of that necessary to crush the column.

Thus: A column has two functions; one to support weight and the other to resist flexure; it follows, then, that when the pressure necessary to break the column is very low on account of the extreme length of it compared with its diameter or depth, then the strength of the whole transverse section of the column will be exerted in resisting flexure. When the breaking pressure is half of what would be required to crush the material, one-half only of the resistance may be considered as available to resist flexure, the other half being exerted in crushing, but when, through the shortness of the column, the breaking weight is so great as to be nearly equal to the crushing force, a very little, if any, portion of the resistance or strength of the column is applied or exerted in resisting flexure.

*To Ascertain the Weight that may be safely borne by Columns of Various Dimensions and Materials.*

RECTANGULAR COLUMNS.

CAST IRON.— $\frac{16000\, l b^3}{4 b^2 + \cdot 18 l^2} = W.$

WROUGHT IRON.— $\frac{18000\ l\ b^3}{4\ b^2 + \cdot 16\ l^2} = w.$

OAK.— $\frac{4000\ l\ b^3}{4\ b^2 + \cdot 5\ l^2} = w.$

SOLID CYLINDERS.

CAST IRON.— $\frac{10000\ d^4}{4\ d^2 + \cdot 18\ l^2} = w.$

WROUGHT IRON.— $\frac{11200\ d^4}{4\ d^2 + \cdot 16\ l^2} = w.$

OAK.— $\frac{2500\ d^4}{4\ d^2 + \cdot 5\ l^2} = w.$

HOLLOW CYLINDERS.

CAST IRON.— $\frac{16000\ D^4 - d^4}{4\ D^2 + \cdot 18\ l^2} = w.$

WROUGHT IRON.— $\frac{11200\ D^4 - d^4}{4\ D^2 + \cdot 16\ l^2} = w.$

OAK.— $\frac{2500\ D^4 - d^4}{4\ D^2 + \cdot 5\ l^2} = w.$

*l representing the length in feet, b the breadth, and* D *and d the diameter in inches, and w the weight in pounds.*

EXAMPLE.—What are the crushing weights that may be safely borne by a cast iron, wrought iron, and oak rectangular column 2 ins. square and 5 feet in height?

$$\frac{16000 \times 5 \times 2^3}{4 \times 2^2 + (\cdot 18 \times 5^2)} = \frac{16000 \times 5 \times 8}{32 + 4 \cdot 5} = 17534\ lbs.$$

for the cast iron.

$$\frac{18000 \times 5 \times 2^3}{4 \times 2^2 + (\cdot 16 \times 5^2)} = \frac{18000 \times 5 \times 8}{32 + 4} = 20000\ lbs.$$

for the wrought iron.

$$\frac{4000 \times 5 \times 2^3}{4 \times 2^2 + (\cdot 5 \times 5^2)} = \frac{4000 \times 5 \times 8}{32 + 12 \cdot 5} = 3596\ lbs.$$

for the oak.

TABLE *showing the Weight or Pressure a Column of Cast Iron will Sustain with safety.*

| | Length or Height in Feet. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| Inch. | | | | | | | | | |
| 2·5 | 13,923 | 12,285 | 10,647 | 9,009 | 7,605 | 6,435 | 5,499 | 4,680 | 3,978 |
| 3· | 20,826 | 19,071 | 16,965 | 14,976 | 12,987 | 11,349 | 9,828 | 8,541 | 7,488 |
| 3·5 | 28,899 | 27,144 | 25,038 | 22,347 | 20,124 | 18,252 | 15,975 | 13,923 | 12,402 |
| 4· | 38,142 | 36,270 | 33,696 | 31,122 | 28,314 | 25,740 | 23,166 | 20,826 | 18,720 |
| 4·5 | 48,906 | 46,800 | 44,343 | 41,418 | 38,259 | 35,217 | 32,175 | 29,367 | 26,793 |
| 5· | 61,074 | 58,617 | 56,043 | 52,884 | 49,959 | 46,098 | 42,705 | 39,439 | 36,270 |
| 6· | 71,019 | 69,264 | 67,041 | 64,350 | 61,425 | 58,149 | 54,873 | 51,480 | 48,321 |
| 7· | 120,744 | 118,521 | 115,713 | 112,203 | 108,108 | 103,779 | 99,216 | 94,536 | 89,505 |
| 8· | 155,961 | 153,855 | 150,813 | 147,303 | 143,208 | 138,645 | 133,614 | 128,349 | 123,084 |
| 9· | 200,772 | 198,549 | 195,624 | 191,880 | 187,551 | 182,637 | 177,255 | 171,639 | 165,672 |
| 10· | 247,923 | 245,700 | 243,009 | 239,265 | 234,819 | 229,788 | 224,172 | 218,205 | 211,887 |
| 11· | 300,690 | 298,350 | 294,840 | 291,330 | 286,650 | 281,970 | 275,886 | 269,685 | 263,016 |
| 12· | 356,850 | 355,680 | 353,340 | 347,490 | 342,810 | 339,300 | 331,110 | 325,260 | 319,410 |

TABLE *Exhibiting the Relative Value of Various Woods, their Crushing Strength and Stiffness being combined.*

| | | | |
|---|---|---|---|
| Teak, | 6,555 | American Spruce, | 2,522 |
| English Oak, | 4,074 | Walnut, | 2,378 |
| Ash, | 3,571 | Yellow Pine, | 2,193 |
| Elm, | 3,468 | Larch, | 1,897 |
| Beech, | 3,079 | Sycamore, | 1,833 |
| Quebec Oak, | 2,927 | Poplar, | 975 |
| Spanish Mahogany, | 2,571 | Cedar, | 700 |

*Comparative Strength of Long Columns of Various Materials.*

| | | | |
|---|---|---|---|
| Cast Iron, | 1,000 | Oak, | 108·8 |
| Wrought Iron. | 1,745 | Pine, | 78·5 |
| Cast Steel, | 2,518 | | |

RESULTS OF EXPERIMENTS

To determine the Resistance of Rectangular and Cylindrical Tubes of Wrought Iron to a Crushing Force applied horizontally in the direction of their length.

RECTANGULAR.

| Length of tubes. | External dimensions. | Thickness of metal. | Weight of greatest resistance. | Area of section. | Weight per sq. inch of greatest resistance. | Weight per sq. inch at which deflection was observed. |
|---|---|---|---|---|---|---|
| Ft. ins. | Ins. | Ins. | lbs. | Sq. ins. | lbs. | lbs. |
| 10 | 4·1 × 4·1 | ·03 | 5,534 | ·504 | 10,980 | |
| 5 | " | " | 5,803 | " | 11,514 | |
| 2 6 | " | " | 6,251 | " | 12,403 | |
| 10 | 4·25 × 4·25 | ·134 | 51,690 | 2·395 | 21,585 | 46,314 |
| 10 | 8·4 × 4·25 | ·26 × ·126* | 206,571 | 6·89 | 29,981 | 99,916 |
| 10 | 8·5 × 8·375 | ·2191 | 198,955 | 7·7367 | 25,716 | |

CYLINDRICAL.

| | | Internal diameter. | | | |
|---|---|---|---|---|---|
| 9 11 | 1·495 | 1·292 | 6,514 | ·4443 | 14,661 |
| 5 | " | " | 13,860 | " | 31,195 |
| 2 6 | " | " | 15,204 | " | 34,221 |
| 9 11 | 2·995 | 2·693 | 37,350 | 1·349 | 27,691 |
| 2 4 | 3· | 2·712 | 52,874 | 1·414 | 37,393 |
| 5 | 3·995 | 3·504 | 86,922 | 2·895 | 30,025 |
| 5 | 3·995 | 3·513 | 98,122 | 2·848 | 34,453 |
| 2 4 | 4· | 3·5 | 136,202 | " | 47,823 |

* Greatest thickness and least depth laid horizontally.

## BRIDGES.

Iron bridges with a circular arc, should have a rise of ·1 of the chord line, and a width of pier of ·1 of span.

*Girders combined with Suspension Chains* (P. W. Barlow).

In a suspended girder, the stress is resisted by back chains or wire rope.

A suspension girder designed for the Londonderry bridge, was rendered equally rigid with a simple girder with less than $\frac{1}{25}$th of the

metal required in the girder above, and from experiments upon a model of the bridge, it was deduced that the deflection of one of the girders when suspended was about $\frac{1}{2\frac{1}{5}}$th of that when the suspension was detached; and, as the girder in the experiment was only suspended at one point, this deflection would be further reduced by suspension at several points, as in the bridge itself.

In suspension bridges, it is essential that the platform should be made as rigid as practicable, to arrest vertical undulations.

The economy of metal in a suspension bridge under the average circumstances of its attainable depth, is from one-fourth to one-half of that in a tubular or simple girder bridge of equal strength and rigidity.

*Comparison between the Two Largest Railway Bridges yet constructed.*

Niagara—Wire. Having a roadway, and a single railway of three gauges in a span of 820 feet; weighs 1000 tons.

Britannia—Tubular. Having a double line of railway in a span of 460 feet; weighs 3000 tons.

### Trussed Beams or Girders.

Wrought and cast iron possess different powers of resistance to tension and compression, or have different tensile and crushing strengths; and when a beam is so constructed that these two materials act in unison with each other *at the stress due to the load required to be borne*, their construction will effect an essential saving of material.

In consequence of the difficulty of adjusting a tension rod to the strain required to be resisted, it is held to be impracticable to construct a perfect truss beam; for, if too high a tension is given to the rod or rods, they will part before the beam has been strained to its yielding point, and, on the contrary, if too low a tension is given to them, the beam will break before it has been strained to its yielding point.

Fairbairn declares that it is better for the tension of the truss rod or rods to be low than high, which position is fully supported by the following elements of the two metals:—

*Wrought iron* has great tensile strength, and, having great ductility, it undergoes much elongation when acted on by a tensile force. On the contrary, *cast iron* has great crushing strength, and, having but little ductility, it undergoes but little elongation when acted on by a tensile force; and, when these metals are released from the action of a high tensile force, the *set* of the one differs widely from that of the other, that of the wrought iron being the greatest. Under the same increase of temperature, the expansion of wrought is considerably greater than that of cast iron; 1·81* tons per square inch is required to produce in wrought iron the same extension as in cast iron by 1 ton.

* The elongation of cast and wrought iron being 5500 and 10,000; *hence*, 10,000 ÷ 5500 = 1·81. Fairbairn, in treating of English metals, gives the elongation as 5450 and 12,300; *hence*, 12,300 ÷ 5450 = 2·25.

The relative tensile strengths of cast and wrought iron being as 1 to 3, and their resistance to extension as 1 to 1·81, therefore, where no initial tension is applied to a truss rod, the cast iron must be ruptured before the wrought iron is sensibly extended.

Fairbairn, in his experiments upon English metals, shows that with a strain of about 12,320 lbs. per square inch on cast iron, and 28,000 lbs. on wrought iron, the sets and elongations are nearly equal to each other; and for strains below 12,320 lbs. and 28,000 lbs., the set of cast iron is greater than that of wrought iron, and for strains above these, the set of wrought iron is the greatest.

From other experiments, he deduced that within the limits of strain of 13,440 lbs. per square inch for cast iron, and 30,240 lbs. per square inch for wrought iron, the tensile force applied to wrought iron must be 2·25 times the tensile force applied to cast iron, to produce equal elongations.

The resistance of the cast iron in a trussed beam is not wholly that of tensile strength, but it is a combination of both tensile and crushing strengths, or a transverse strength; *hence*, in estimating the resistance of a girder, the transverse strength of it is to be used in connexion with the tensile strength of the truss.

The mean practical transverse strength of a cast iron bar, one inch square and one foot in length, supported at both ends, the strain applied in the middle, is about 900 lbs.; and as the mean practical tensile strength of wrought iron is about 20,000 lbs. per square inch, the ratio between the sections of the beams and of the truss, should be in the ratio of the transverse strength per square inch of the beam and of the tensile strength of the truss.

The girders under consideration are those alone in which the truss is attached to the beam at its lower flanch, in which case it presents the following conditions:—

1. *When the truss runs parallel to the lower flanch.*

2. *When the truss runs at an inclination to the lower flanch, being depressed below its centre.*

3. *When the beam is arched upwards, and the truss runs as a chord to the curve.*

Consequently, in all these cases the section of the beam is that of an open one with a cast iron upper flanch and web, and a wrought iron lower flanch, increased in its resistance over a wholly cast iron beam, in proportion to the increased tensile strength of wrought iron over cast iron for equal sections of metals.

As the deductions of Fairbairn as to the initial strain proper to be given to the truss are based upon a cast iron beam with the truss inserted with the upper flanch of the beam, whereby it was submitted almost wholly to a tensile strain; they will not apply to the two constructions of trussed beams under consideration. As each construction of trussed beam will produce a strain upon the truss in accordance with the position of the neutral axis of the section of the whole beam, and as the extension of the truss will vary according as it is

more or less ductile; it is impracticable in the absence of the necessary elements to give an amount of initial strain that would be applicable as a rule.

From the various experiments made on trussed beams, it is shown:

1. That their rigidity far exceeds that of simple beams; in some cases, it was from 7 to 8 times greater.

2. That when the truss resists rupture, the upper flanch of the beam being broken by compression, there is a great gain in strength.

3. That their strength is greatly increased by the upper flanch being made larger than the lower one.

4. That their strength is greater than that of a wrought iron tubular beam, containing the same area of metal.

(To be Continued.)

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### *Census of France.*

The following interesting table is taken from the *Cosmos*, and gives the comparative number of inhabitants in France in 1851 and 1856, with their means of support:

| | 1851. | 1856. |
|---|---|---|
| Agriculture, . . | 21,992,874 | 19,061,071 |
| Arts and Commerce, . | 9,233,895 | 12,202,391 |
| Liberal Professions, . . | 3,483,538 | 3,262,282 |
| Without Profession, . | 1,022,063 | 1,483,925 |
| | 35,732,370 | 36,009,669 |

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### *Relations between the Densities and Atomic Weight of the different varieties of Carbon.* By L. PLAYFAIR.

It is known that (calling $d$ the density of a simple body; $p$, the atomic weight; $v$, the atomic volume) we have $\frac{p}{d} = v$. On the other hand, the densities of carbon are, from the average of the determinations: in the state of the diamond, 3·46; graphite, 2·29; charcoal, 1·88. Substituting these values for $d$, and remarking that the equivalent of carbon in its three forms is essentially the same, and equal to 12, we find for the atomic volume in these three states: diamond, 3·46; graphite, 5·24; charcoal, 6·38. But we also have $\sqrt{12} = 3{\cdot}364$; $\sqrt[3]{12} = 2{\cdot}289$; $\sqrt[4]{12} = 1{\cdot}865$.

Whence Mr. Playfair concludes that if we square the density of the diamond, cube that of graphite, and raise that of charcoal to the fourth power, we get sensibly the same number 12. That is to say, calling these three densities $d$, $d'$, and $d''$, we have sensibly, $d^2 = 12$; $d'^3 = 12$; and $d''^4 = 12$, and consequently,

$$d' = \sqrt[3]{d^2} = d^{\frac{2}{3}}; \quad d'' = \sqrt[4]{d^2} = d^{\frac{1}{2}}.$$

*Cosmos*, Jan., 1861, p. 37.

Translated for the Journal of the Franklin Institute.

*Silvering Mirrors.* Process of MM. BROSSETTE & Co. Patented in France, 1855.—*Report of the Committee of the Society for the Encouragement of National Industry of France.*

After the surface of the glass to be silvered has been cleaned with Spanish whiting and water, it is rubbed over with jeweller's putty (oxide of tin), with some ammonial nitrate of silver added to it; this is the same salt which is afterwards used in the silvering.

Before proceeding to silver, the glass as it lies on its supports, is washed with a caoutchouc roller soaked in distilled water, and then placed truly horizontally on a cast iron table covered with oil-cloth, which forms the upper part of a rectangular trough filled with water whose temperature is raised to 60°-Cent. (140° Fah.) by means of steam. When this has been done, there is poured upon the glass a solution 100 parts by weight of nitrate of silver dissolved in 500 parts of distilled water and 69 parts of liquid ammonia of sp. grav. 0·87 or 0·88; to this is added drop by drop after filtration 7½ parts of tartaric acid first dissolved in 30 parts of distilled water. This liquid (solution No. 1) is retained on the surface of the glass by simple capillarity. It is left about 15 minutes, care being taken that every part which is to be silvered shall be well moistened with it, and at the end of this time the glass is inclined and the liquid allowed to run off, mixed with a considerable quantity of non-adherent silver, into grooves arranged around the table; it is then washed, and after being replaced in its former position, the second coating of silvering is applied (solution No. 2), which differs from the first only in containing a double quantity of tartaric acid. This must remain on for 25 minutes, after which, the glass after being washed with distilled water is laid in a very oblique position, and then covered with a coating of red lead and oil, which dries rapidly.

The first coating itself produces a coating which reflects perfectly, but which, although adhering strongly, would not be solid enough to receive the coating of paint; if the glass in this condition be held up to the light, many defects in the coating will be seen, which disappear after the second coating.

According to the experiments of the committee, the first coating represents about 12 grammes of silver to the square metre (17·2 grs. per sq. foot), and the two coatings together 29 grammes (41·57 grains per sq. foot). There would perhaps be an advantage in prolonging the contact of the liquids with the glass, as experiment shows that they continue to deposit their silver for several hours after their decantation; yet the liquid always retains at least one-half of the silver in solution.

This process (the committee says) gives satisfactory results both for plane and curved mirrors; and for the ordinary mirrors found in commerce, the expense does not exceed that of the ordinary method, over which it has the advantage of not being endangered by being put in any position either while carrying or when hung. It also appears to have the advantage of not being affected by moisture or exposure to

sun-light. But they are not proof against vapors containing sulphuretted hydrogen; these, especially when aided by moisture, are not completely guarded against by red lead.—*Bulletin de la Societè d'Encouragement pour l'Industrie Nationale*, May, 1860.

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For the Journal of the Franklin Institute.

*Upon the Practical Relative Economy of using Steam with Different Measures of Expansion.* By ALBAN C. STIMERS, Chief Engineer, U. S. Navy.

The most simple and obvious mode of using steam to obtain power in a steam engine, is to permit it to flow freely from the boiler into the cylinder during the entire stroke of the piston; and this was the plan adopted in the earliest engines.

The ingenious and philosophical mind of Watt, however, upon the announcement by Mariotte that the volume of the fixed gases, when maintained at a constant temperature and unaffected by the greater or less proximity of their molecules, was inversely as their pressure, or, conversely, that the pressure was inversely as their volume, soon made the application to steam; and, assuming this law and this application of it to be correct, it is easily shown that great gains in economical effect are produced by suppressing the flow of steam into the cylinder before the piston has completed its stroke, and permitting it to expand during the remainder. This was done by Watt, and apparatus for effecting this suppression at any desired point in the stroke, forms one of his many patents; but, notwithstanding the fact that both his mechanism and his patent covered the whole ground of the expansion question, that is, enabled him to cut off at any point in the stroke, his engines, which were generally paid for by a portion of the fuel he saved over that used by those displaced, were arranged, after a few trials, for suppressing the steam at about three-fourths the stroke of the piston.

Any one familiar with Watt's history must have observed how uniformly he put every important conception tending to improve the steam engine to the test of a practical experiment; and though we have no account of an especial set of experiments having been tried by him to test the exact value of the expansion principle, there is but little doubt that his very accurate practice would soon determine whether the practical result was equal to the theoretical prediction, and that, when he found it was not, he determined by a complete set of experiments the most favorable degree of expansion and its actual value in the practical steam engine. The fact that he published no account of such experiments is no proof against their having been made, as he had every incentive as a business man to permit his rivals to follow the natural proneness of mankind for settling all such questions by mathematical demonstration rather than by carefully-conducted experiments, which require time, money, ingenuity, patience, and a much greater knowledge of the physical laws, for drawing correct inferences from the experimental data than is needed in any cal-

culation where the data is all assumed; having ascertained to his own satisfaction that all such calculations, based upon his own invention, the indicator diagram, would lead them to adopt a more unfavorable degree of expansion than had been decided upon for him by his experiments, thus causing them to produce engines inferior to his own.

The steam engine establishment of Boulton and Watt is still in existence, having descended from father to son during eighty-six years, and the general practice of the present firm with regard to this question is the same to-day that it was sixty years ago. It cannot be considered as at all strange that the practice of so successful and celebrated an establishment should be imitated as closely as possible by a large majority of steam engine builders as soon as the expiration of their patents destroyed their monopoly; and this we find to have been the case in fact, even in our own country. The swift and powerful steamers upon the Hudson, in their palmiest days, only differed materially from the practice of the above establishment by using a higher pressure, the steam being cut off almost uniformly at five-eighths of the stroke of piston. The same degree of expansion is also used in the engines of the steamers upon the Mississippi and its tributaries.

It is true that in river boats the greater dimensions and consequent weight of the larger engines required to use the steam very expansively may be a much greater objection than it is in most of the applications of steam power, and that, consequently, the fact of the lesser degree of expansion being used in them, is not in itself a proof of its greater economy; but, an examination of the subject will prove that the advantages of obtaining great power with small engines are not, in either of these instances, at the expense of economy in fuel.

Until quite recently, it was the exception, and not the rule, to find new engines cutting off at less than half the stroke of the piston, and even now it is doubtful if a majority of all the steam engines in existence are arranged for expanding the steam as much as twice. The impression, therefore, which appears to be quite general, that any experiments which prove that the law of Mariotte cannot be applied to the practical steam engine to determine its economy when the steam is being expanded several times, are contrary to the experience of the whole engineering profession ever since its birth, is a very mistaken one. The indefatigable persistence, however, of the patentees of adjustable cut-offs, who wish to "sell rights," together with the remarkable coincidence which exists between the indicator diagram as formed by an engine when expanding the steam several times, and that called for by the simple application of the law of Mariotte, have exerted of late years a powerful influence in causing engines to be built with the design of permitting the steam to expand a great number of times.

The apparent success of some of the extreme applications lately made of this principle, was rapidly causing a great revolution in the practice of the profession; so much so, that when Chief Engineer Isherwood, of the U. S. Navy, had the practical sagacity to perceive that the actual economy of any engine in which the steam was greatly expanded was not nearly equal to what it should have attained if there

had been no drawbacks to the application of the theory, and proceeded to publish a book, giving, among other things, an account of experiments he had made to test the question, and explaining their rationale, it was met with severe criticism from nearly every quarter. He was looked upon as a man who was endeavoring to thrust the steam engine back into the darkness from which it was just emerging. By no one was this view taken more strongly than by the present writer, who shared the general feeling that the experiments detailed in the book were not of a character to justify its author in what appeared to be such radical conclusions, overthrowing, at one fell stroke, all our preconceived ideas respecting the power of the indicator diagram to determine the amount of steam which had entered the cylinder.

After the issue of the above book, and during the year 1860, Mr. Isherwood was almost constantly engaged, under orders from the Navy Department, in experiments showing the relative economy of using steam with different manners of expansion. Such of the results of these as became known to the public, were so different from what would have been predicted by what had become to be regarded as established theories, that a memorial was addressed by a large number of steam engine manufacturers and others, to the Secretary of the Navy, praying him to cause a complete set of experiments to be tried with the engines of some of our national vessels by a Board of Naval Engineers. This was granted, and a Board, consisting of Chief Engineers B. F. Isherwood, Theodore Zeller, Robert H. Long, and Alban C. Stimers, was ordered to convene on board the U. S. Steamer *Michigan*, at Erie, Penna., on the 19th of November, 1860.

When the writer joined this Board, he had very little doubt about the result. He had been taught in his engineering education to consider the indicator diagram as an exponent of the economy of the engine which formed it, whatever the degree of expansion, and although he had experienced some unaccountable deficiencies in the evaporative powers of boilers attached to engines using large measures of expansion, he had never suspected that the difficulty lay in the engines and not in the boilers or the coal. And as an experiment was not in itself an argument upon this side or that of any question, but the true determination of the real facts; he believed that these would prove to be, that decided benefits were obtained by expanding the steam as many as three times at least in that kind of engines, namely: unjacketed cylinders using saturated steam, and without regard to the opinions or expectations of the others, he satisfied himself thoroughly of the propriety of every preparation made before commencing the experiments and watched narrowly their whole conduct afterward; being determined that whatever they would be to people in general, to him they should prove the *experimentum crucis*, as far as these engines were capable of determining the question. This they have done, and they prove to his entire satisfaction that it is utterly futile to attempt to realize any benefit by expanding the steam beyond one and a half times, under the conditions above described.

The following description of the machinery; of the manner of making

the experiments; of obtaining the data; and of calculating the results; together with the reasons for the same, and the reductions formed, may be considered as condensed from the Report of the Board, which being very minute and circumstantial, is too long for a magazine article.

The selection by the Navy Department of the machinery of the U. S. Steamer *Michigan* for making these experiments was determined by its appropriateness and convenience; the engines being of the medium size used for marine purposes and the vessel out of commission; the former had just been thoroughly repaired and furnished with new boilers.

*Description of the Boilers.*—The boilers are two in number, placed side by side, six inches apart, with one smoke-pipe in common at the front end. They are of the type known as *Martin's patent*, but with proportions somewhat different from those adopted by the patentee; these were designed by Samuel Archbold, Esq., the Engineer in Chief of the Navy, for the purpose of burning to the greatest advantage the highly gaseous coal found on the borders of Lake Erie, in Pennsylvania and Ohio, and universally used by the steamers on the lakes, to the waters of which the cruising of the *Michigan* is confined.

These peculiarities are:

1. The greater length of the tube-box, which is about one and a half times more than the patentee employs.

2. The greater width in the clear between the tubes crosswise the furnaces, which is about two and a half times that which the patentee employs.

3. The greater calorimeter for draft between the tubes, which is double the patentee's proportion, while the area of the smoke-pipe, instead of being equal to this calorimeter, is only about half of it.

4. The employment of a much larger combustion chamber between the furnace and the tubes than the patentee adopts.

5. The furnishing a copious supply of air, not only to the furnaces through perforations in the doors, but to the bottom of the combustion chambers, through perforations in the lower part of the bridge-wall.

The whole of the boilers and steam chimney are well covered with felt. The heating surface given below is calculated for every part with which the heated gases come in contact—top, sides, and bottom—and for the external circumference of the tubes.

The following are their principal dimensions:—

| | |
|---|---|
| Length of each boiler at the furnaces (fore and aft the vessel), | 15 feet 8 inches. |
| " " at top of flues, | 16 " 8 " |
| Breadth " | 9 " 2 " |
| Height " exclusive of steam chimney, | 9 " 2 " |
| Number of furnaces in each boiler, | 3. |
| Width of each furnace, | 2 " 6 " |
| Length of grate bars, | 6 " |
| Height from bottom of ash-pit to top of grate bars at front of furnace, | 1 " 9 " |
| Height of crown of furnace from bottom of ash-pit at front of furnace, | 4 " |
| " " from top of bridge-wall, | 1 " 3 " |
| External diameter of tubes, | 2 " |
| Length of tubes between tube sheets, | 1 " 8 " |
| Whole number of tubes, | 1504. |
| Total area of grate surface, in both boilers, | 90 sq. ft. |
| " of water-heating surface, in both boilers, | 2689·59 " |
| " of steam-heating " " | 84·71 " |

Diameter of the smoke-pipe, . . . 4 feet 3 inches.
Height " above grate surface, . 45 "
Steam space in the two boilers and steam chimney, 530 cub. ft.
Weight of water in the two boilers, at a temperature of 262° Fahr., measured to the height carried during the experiments, 46,450 lbs.

PROPORTIONS.—Ratio of water heating to grate surface, . 29·884 to 1.
" steam " " . 0·941 to 1.
" grate surface to least cross area betw'n tubes, 3·212 to 1.
" " to area of smoke-pipe, . 6·344 to 1.

*Description of the Engines.*—The engines are two in number, condensing, direct-acting, and inclined from the keel at an angle of 23 degrees: they are placed side by side in the vessel with a passage-way 4¼ feet wide between them. They occupy in the vessel a space 15 feet wide, including the above passage between them, by 35 feet long, and a height from top of keelsons to top of main pillow blocks of 13½ ft.

The air-pump is inclined like the cylinder, the axis of both being parallel. It is a single-acting piston-pump, with a solid piston, and one end open to the atmosphere.

The condenser is the common jet kind, situated immediately beneath the cylinder.

The cylinder steam and exhaust valves are the double poppet kind habitually used in the United States for marine paddle-wheel engines. The upper and lower valve chests are connected by a steam and an exhaust pipe, the axes of which are parallel with the axis of the cylinder.

The cylinder steam valves are made to act as expansion valves by means of a valve-gear known as *Sickle's cut-off*. As applied to these engines, the valve was tripped by its own movement when the spring came in contact with the inclined face of a fixed cam, which could be adjusted by means of a screw. By this arrangement, the point of cutting-off could be graduated from nearly the commencement up to ⅜ of the stroke of the piston, and from $\frac{7}{10}$ up to $\frac{11}{12}$ of the stroke, at which point the valve seated by the eccentric movement without tripping. Between ⅜ and $\frac{7}{10}$ of the stroke it was impossible to suppress the admission of the steam.

Each end of the cylinder is provided with a relief valve for the discharge of the waste water.

The steam pipe between the boilers and cross pipe to the two engines, in which is placed a throttle valve to each engine, is 25¼ feet long by 17¾ inches diameter. The cross pipe is 4¾ feet long by 15¼ inches diameter, and the steam side pipe of each cylinder is 7½ feet long by 12¼ inches diameter, giving a total interior surface when one engine is used, for the radiation of the heat, of 156·5 square feet, and as there is a slight inclination towards the cylinder throughout the whole length of the steam pipes, any water condensed in them is passed through the cylinder.

The steam pipes, side pipes, and cylinders are protected with a thick coat of felt covered with wooden lagging. The heads of the cylinders, the valve chests, and cylinder nozzles have no covering.

The lower head of each cylinder is double, the upper one is single.

| | | |
|---|---|---|
| Diameter of cylinder, | | 36 inches. |
| Stroke of piston, | 8 feet. | |
| Diameter of piston rod, | | 3¼ " |
| Mean area of piston, exclusive of rod, | 1012·278 sq. ins. | |
| Space displacement of piston per stroke, excl. of rod, | 56·514 cub ft. | |
| Steam space comprised in the clearance and nozzle, | 3·280 " | |
| Net area of opening through steam valve, exclusive of stem, &c., | 114·96 sq. ins. | |
| Net area of opening through exhaust valve, exclusive of stem, &c., | 108·38 " | |
| Diameter of air-pump, | | 29 " |
| Stroke of air-pump piston, | | 31½ " |
| Space displacement of air-pump piston per stroke, | 12 cub. ft. | |
| Diameter of feed pump and of bilge pump, | | 5 7-16 " |
| Stroke of piston of " " | | 31½ " |
| Capacity of one condenser, | 20 " | |
| " hot-well, | 27 " | |
| Length of connecting rod, | 16 " 5 " | |

PADDLE WHEELS.—The arms, rims, and braces of the paddle-wheels, are of iron; the paddles are of wood, 1¼ inches thick, chamfered at the edges. Each paddle is divided in its breadth.

| | | |
|---|---|---|
| Diameter to outside of paddles, | | 21 feet 6 inches. |
| Number of paddles in each wheel, | 16. | |
| Breadth of outer fraction of paddle, | | 1 " 2 " |
| " inner " | | 1 " 5 " |
| Length of paddles, | | 8 " |
| Immersion of the lower edge of paddle, | | 2 " 8 " |

NOTE.—The above is the normal surface and dip, but during the experiments these greatly varied, different numbers of buckets being removed for different experiments, and sometimes several getting broken by the ice during the same experiment. The vessel, too, was so near the ground, that, as the water ebbed and flowed by the influence of the winds, it was sometimes afloat and sometimes aground, varying the dip according to the extent of the fall of the water: the experiments being made with the vessel lashed to the wharf in the harbor of Erie.

*Manner of Making the Experiments.*—The experiments were made with the starboard engine alone and with both boilers. The following are the quantities and the mode of obtaining them, which were ascertained by direct measurement or weights.

The number of double strokes made by the engine piston were registered by one of Rogers' engine counters.

The number of pounds of coal consumed, of ashes, clinker, and soot, forming the refuse from the coal, were accurately weighed on one of Fairbanks' platform scales, quite new, and tested previous to its being used.

The steam pressure in the boilers was shown by one of Allen's spring gauges and by a mercurial syphon gauge, the two coinciding.

The vacuum in the condenser was denoted by one of Allen's spring vacuum gauges.

The steam pressure in the cylinder throughout the stroke of the piston, was obtained by taking indicator diagrams hourly from each end of the cylinder with excellent instruments of the New York Novelty Iron Works manufacture. Those shown in the plate are fair samples of those taken during each experiment.

The pressure of the atmosphere was denoted by an aneroid barometer, which hung in the centre of the engine room. This was used to determine in each case the back pressure in the cylinder.

The temperatures of the injection water, of the feed water in the tank, of the external atmosphere, and of the engine room, were measured by thermometers of the ordinary description; that of the hot-well was shown by a large fixed thermometer having its bulb constantly immersed in the water in the interior of the well.

The feed water, before being pumped into the boilers, was first pumped into a wooden tank lined throughout with zinc, and as the hose through which the water was each time pumped into it and the pipe through which it was withdrawn by the feed pump passed over the top, there were no joints to cause leakage. In addition to this precaution against error in measuring the amount of water evaporated, the tank was blocked up from the engine room floor 3 inches; so that if any leakage should occur from any cause, it would be immediately discovered. The internal dimensions of the tank were as follows:—length $11\frac{1}{4}$ feet, breadth $1\frac{3}{4}$ feet, height $3\frac{7}{8}$ feet. It was filled each time to a convenient mark which corresponded accurately with a capacity of 70 cubic feet. Great care was taken in making the connexions between this tank and the feed pump to shut off absolutely every other source from which the pump could be supplied, and to close all avenues of egress from the pump except those which conducted the water to the boilers.

The boilers were fitted with the usual gauge cocks and with glass water gauges; these latter enabled the height of the water within to be noted with great exactness by tying a piece of small twine around the glass tube at the height of the water. When an experiment was commenced, the piece of twine was made to correspond exactly with the water level, which was brought again to the same level at the end of the experiment.

The water supplied to the boilers being fresh and almost absolutely pure, no blowing off was required; all the water, therefore, which was measured in the tank was available for making steam. Great care was taken before commencing the experiments to have all valves and cocks through which water or steam could leak from the boilers made absolutely tight, and afterwards a regular system of inspection was adopted that any new leak might be at once discovered. With regard to the boilers themselves, they were quite new, and, as far as could be ascertained by the most rigid scrutiny, were absolutely tight.

Each experiment lasted 72 consecutive hours, during which the engine was neither stopped, slowed down, nor in any way changed in condition. In commencing an experiment, the engine was operated for several hours to adjust it to the normal conditions required to be uniformly maintained during that experiment and to bring the fires to steady action. When all was ready, average fires and the proper steam pressure being in the boilers, the time and number of the engine counter were noted, and the experiment began. From this time up to the end of the 72 hours all the quantities were weighed or measured and

noted hourly in a regular *log*, ruled with appropriate columns. As the end of the experiment approached, care was taken to bring the fires to the same state of cleanliness and to the same thickness which they had at the beginning. The means or totals then, as the case required, of the quantities entered in the log furnished, with the exception of the facts derived from the indicator diagrams, the data for that experiment.

Each of the 144 diagrams taken during one experiment was carefully analyzed and its results arranged in tabular form, so that the mean of the whole number was conveniently obtained by getting the mean of the whole number of quantities in each column of the table. The quantities thus found were,

The pressure in the cylinder at the commencement of the stroke,
The pressure in the cylinder at the point of cutting off,
The final pressure at the end of the stroke of the piston,
The mean back pressure,
The mean gross effective pressure, and
The fraction of the stroke completed when the steam was cut off.

At the close of the experiments, the pressure on the piston required to operate the engine *per se* was obtained by removing all the paddles from the wheels and running the engines, taking indicator diagrams to get the pressure. Of course the arms of the paddle wheels acted, to a certain extent, propulsively upon the water, and to eliminate this quantity the engine was run at various speeds, ranging from 8 to 22 double strokes per minute, and taking several sets of diagrams for each rate of speed to get a reliable mean. Now, the resistance to the passage of the paddle wheel arms through the water was variable and required an increased piston pressure with each increase in the speed, while the piston pressure required to overcome the friction of the engine would be constant for all speeds; by eliminating, then, the variable quantity, the constant quantity remaining would be the correct pressure required solely for overcoming the friction. This was found to be 2·1 pounds per square inch.

In reporting the experiments, the Board make out two tables containing all the data and results observed and calculated; embracing only those trials in which all the conditions from beginning to end were such as could satisfy the most hypercritical, and moreover they are those which give the highest results to the greater measures of expansion. The first table contains the exact experimental determinations under the conditions noted, and is made out in great detail. The second contains the results detailed in the first, but calculated only for weight of steam used in rapport of power developed, and corrected for equality of back pressure against the piston, which equality did not obtain in the experiments, but which it is necessary to adopt in order to show the *true* relative economy of the different measures of expansion employed; for whatever absence of back pressure can be obtained in one case can in any other. This second table of the Report contains, therefore, all that is really essential to a correct understanding of the results obtained by the experiments, and is the only one of the two given in this paper.

TABLE: *Containing the Results of the Experiments, calculated for Equality of Back-pressure against the Piston, and showing the True Relative Economy of using Steam with Different Measures of Expansion.*

| | | | Fraction of Stroke Completed when Steam was Cut Off. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 11/12 | 7/10 | 4/9 | 3/10 | 1/4 | 1/6 | 4/45 |
| 1 | Steam Pressure in Cylinder per Indicator | In pounds per square inch above zero at beginning of stroke of piston, | 34·8 | 33·3 | 34·5 | 34·4 | 34·3 | 34·2 | 34·7 |
| 2 | | " " " at point of cutting off the steam, | 32·2 | 31·4 | 33·0 | 33·4 | 33·3 | 33·2 | 33·0 |
| 3 | | " " " at end of stroke of piston, | 29·3 | 22·2 | 15·7 | 11·0 | 9·7 | 7·8 | 5·9 |
| 4 | | " " " against piston during the stroke, | 2·7 | 2·7 | 2·7 | 2·7 | 2·7 | 2·7 | 2·7 |
| 5 | | Mean gross effective pressure in pounds per square inch on piston during its stroke, | 31·3 | 28·4 | 24·4 | 20·2 | 17·4 | 13·7 | 9·8 |
| 6 | | Pressure in pounds per square inch on piston, required to work the engine, *per se*, | 2·1 | 2·1 | 2·1 | 2·1 | 2·1 | 2·1 | 2·1 |
| 7 | | Mean net effective pressure in pounds per square inch of piston, | 29·2 | 26·3 | 22·3 | 18·1 | 15·3 | 11·6 | 7·7 |
| 8 | | Per centum which the mean net effective pressure is of the total pressure, | 85·9 | 84·6 | 82·3 | 79·0 | 76·1 | 70·7 | 61·6 |
| 9 | Power Absolute. | Gross effective horses power developed by the engine, | 316·604 | 216·905 | 206·966 | 135·727 | 118·434 | 75·095 | 67·821 |
| 10 | | Total horses power developed by the engine, | 343·915 | 237·527 | 220·868 | 153·869 | 136·812 | 89·895 | 86·506 |
| 11 | | Net horses power usefully applied, | 295·362 | 200·867 | 189·153 | 121·617 | 104·140 | 63·584 | 53·288 |
| 12 | Power Economic. | Pounds of steam consumed per hour per gross effective horses power, | 38·029 | 33·817 | 32·671 | 34·681 | 34·472 | 36·769 | 41·382 |
| 13 | | " " " total " | 35·008 | 30·881 | 29·416 | 30·592 | 29·841 | 30·715 | 32·044 |
| 14 | | " " " net " | 40·763 | 36·561 | 35·748 | 38·705 | 39·202 | 43·425 | 52·669 |
| 15 | Comparative. | Speed of the piston in feet per minute, | 329·744 | 248·967 | 276·512 | 219·040 | 221·888 | 178·688 | 225·600 |
| 16 | | Comparative bulks of steam withdrawn from the boilers in equal times, | 1·000 | 0·609 | 0·561 | 0·391 | 0·339 | 0·229 | 0·233 |
| 17 | | Mean total pressure on piston in pounds per square inch, by Mariotte's law, | 34·5 | 31·3 | 27·6 | 23·2 | 21·2 | 17·2 | 12·6 |
| 18 | | " " " by experiment, | 34·0 | 31·1 | 27·1 | 22·9 | 20·1 | 16·4 | 12·5 |
| 19 | | Comparative economic result, by Mariotte's law, for the total horses power, | 1·000 | 0·835 | 0·660 | 0·568 | 0·532 | 0·475 | 0·422 |
| 20 | | " by experiment, for the gross effective horses power, | 1·000 | 0·889 | 0·855 | 0·912 | 0·906 | 0·967 | 1·088 |
| 21 | | " " total " | 1·000 | 0·882 | 0·840 | 0·874 | 0·852 | 0·877 | 0·915 |
| 22 | | " " net " | 1·000 | 0·896 | 0·877 | 0·949 | 0·962 | 1·065 | 1·292 |
| 23 | | Comparative capacity of cylinder required to develop equal net horses power, | 1·000 | 1·110 | 1·309 | 1·613 | 1·909 | 2·517 | 3·792 |
| 24 | Condensation. | Weight of steam condensed in the cylinder due to the heat annihilated in producing the total power, according to Joule's equivalent; expressed in per centum of the feed-water, | 7·80 | 8·74 | 9·04 | 8·59 | 8·77 | 8·45 | 7·94 |
| 25 | | Discrepancy between the tank and indicator measurements of the feed-water; expressed in per centum of the latter, | 2·91 | 6·60 | 18·14 | 33·07 | 30·84 | 33·66 | 37·16 |

### Explanation of the Table.

For facility of reference, the quantities are arranged in groups, and the lines containing them numbered.

Line 4 contains the corrected back-pressure above zero, in pounds per square inch against the piston during its stroke. The quantity 2·7 pounds was adopted for this purpose, because it is the least given during the experiments, and as with equal initial cylinder pressures the results are more unfavorably affected by back-pressure as the steam is used more expansively, it was deemed proper to accept the least practicable. The average with steam engines under the conditions of ordinary practice, is about 4 pounds, which, if adopted, would make the economic results much less favorable to the greater measures of expansion.

Lines 5 and 7 have been corrected from the experimental determinations to what they would have been, had the back-pressure been uniformly 2·7 pounds.

Lines 9, 10, and 11, contain, respectively, the gross effective, the total, and the net indicated horses power developed by the engine when using the pressures given on lines 5, 18, and 7, and having a speed of piston corresponding to those given on line 15.

Lines 12, 13, and 14, contain, respectively, the number of pounds of feed-water consumed per hour to produce the gross effective, total, and net indicated horses power, as given before.

Line 17 contains the mean total pressure, or pressure above zero on the piston, in pounds per square inch, that should exist according to the law of Mariotte. It is calculated for the experimental conditions of the steam comprised in the clearance and cylinder nozzles, and of the cylinder pressures at the beginning of the stroke, and at the point of cutting off the steam (lines 1 and 2). By comparing the quantities on this line with those on line 18, which are the mean total pressures on the piston as shown by the indicator, a remarkable coincidence will be found. That it is only a coincidence, is evident when it is remembered that, in order that the one should be a consequence of the other, it would be necessary that neither condensation, from any cause, nor re-evaporation should have occurred in the cylinder, from the point of cutting off to the end of the stroke of the piston, and that the steam should have expanded precisely in the inverse ratio of the spaces occupied.

Line 19, exhibits, comparatively, the economic result that should have been obtained with the different measures of expansion used for the steam, according to Mariotte's law. The calculation is made for the total horses power developed, and for the conditions which were obtained in the experiments, with the exception, only, that the steam is supposed to follow this law, agreeably to the general belief among engineers. In order to ascertain how nearly the steam comes up to the assumed law, in the ordinary steam engine cylinder, it is only necessary to compare the quantities in this line with those on line 21, which show the comparative cost of obtaining a given total horse

power, with the different measures of expansion employed, as determined by the experiments.

It is plain from these figures that the law of Mariotte cannot be employed to determine, even approximately, the economy of any engine which is using the steam expansively to any extent; although, in calculations for simply determining the power, it appears to be as safe a reliance as has all along been supposed by the most firm believer in its applicability to steam when expanding in an engine cylinder. Indeed, engineers were in the habit of making this comparison, which is readily done from the indicator diagram itself when the clearance is known, and it was one of the evidences which satisfied the mind that there was no danger of making any material error in taking the diagram as an exponent of the economy of the engine. Any difficulty in getting the expected economy from large measures of expansion, always appeared to be that the boilers failed to evaporate the proper amount of water per pound of coal, and either they or the coal itself were condemned as not being equal to expectation: the guilty engine not being even suspected.

Line 22 gives, comparatively, the cost in fuel of a given useful effect produced by the engine, and determines, *per se*, the practical relative economy with regard to fuel alone, of using steam with the different measures of expansion employed. To determine, however, the propriety of designing an engine with the view of using the most economical measure of expansion employed in the experiments, it is necessary to consider, in connexion with this, the quantities on line 23, which show the comparative capacity of cylinder required to produce, *cæteris parabus*, a given power with the net effective pressures given on line 7. The weight, space occupied, and first cost of steam engines proper, decrease in a more rapid ratio than the capacities of their cylinders. It is, therefore, perfectly safe to assume that these quantities vary with those on line 23, and, when this is done, an estimate, however roughly approximative, points inevitably to the fraction of $\frac{7}{16}$ as being the most economical one for cutting off the steam.

Lines 24 and 25 exhibit the difference, due to all causes, between the weight of feed-water pumped into the boilers, according to the tank, and the weight of steam discharged from the cylinder into the condenser at the end of the stroke of the piston, per indicator, expressed in per centums of the feed-water. Line 24 shows that part of it which is condensed in consequence of the heat annihilated in the cylinder to produce the total power developed by the engine, according to Joule's equivalent of one pound of water raised one degree of temperature on Fahrenheit's scale for every 772 foot-pounds developed by the engine; which would make the thermal equivalent of one indicated horse power, $\left(\frac{33{,}000}{772} = \right)$ 42·7461 pounds of water raised one degree Fahrenheit.

To make the calculation, let $k$ = the number of *total* indicated horses power (line 10), developed by the engine; $e$ = the total heat

of steam of the pressure at the end of the stroke of the piston (line 3), in degrees Fahr. according to Regnault; $g$ = the temperature in degrees Fahr. of the same steam; and $t$ = the time in minutes ($60 \times 72 = 4320$) during which the power, $k$, acted: then, $\frac{k \times 42{\cdot}7461 \times t}{e - g}$ = the number of pounds of steam condensed from this cause during one experiment. The per centum which this total quantity is of the total quantity pumped into the boilers during the experiment, is then obtained for the quantities on line 24.

The causes of the remaining differences, given on line 25, may be numerous. If the boilers lose water by leakage, by priming, or by passing it over to the cylinder in the vesicular state, the quantity thus lost will be included. If the cylinder valves or the piston leak steam to the condenser, the quantity thus leaked will be included. If the steam be condensed in the steam-pipe, valve-chests, or cylinder, from any causes other than the production of the power, and if a portion of the water formed by this condensation be re-evaporated in the cylinder, then the difference of the weights condensed and re-evaporated will be included. By taking these quantities into consideration when comparing the economic results for total powers that should have been obtained according to the law of Mariotte (line 19) with those obtained by experiment (line 21), a very clear idea will be had of the great antagonistic cause that neutralizes and reverses the economy promised by the purely abstract conditions on which that law is founded.

## Discussion of the Results.

*The Initial Pressure.*—In examining the preceding table, it will be observed that particular care was taken to maintain the initial cylinder pressure (line 1) the same in all the experiments as nearly as practicable. That this is a proper condition for the purpose of the experiments, will be obvious when it is considered that degree of pressure is purely a question of boiler, and not at all one of engine. It is just as feasible to carry a high pressure and cut off the steam at $\frac{7}{10}$ of the stroke of the piston, as it is when cutting off at $\frac{1}{10}$, if the cylinder of the engine be of the proper dimensions. In considering subjects of this nature, it is very important that they be properly analyzed, so that but one element is determined at a time. To give the larger measures of expansion the benefit which is due to a higher pressure of steam, is not the way to ascertain how much benefit there is to be derived from expansion *per se*,—the object of these experiments.

It is, however, very useful to know the relative economy of developing, in the same engine, the same power with different measures of expansion; the greater measures having a correspondingly higher initial pressure in the cylinder, so that equal mean net pressures are exerted upon the piston during its stroke. The principal gain in using a higher pressure of steam in the cylinder of a steam engine, is to reduce the per centum of loss by the sum of the back and friction pressures, but when comparing results from *total* pressures alone, this element could not of course enter into consideration. Now, if we have

with the different measures of expansion, different initial pressures, such as the *net* pressures are equal, we shall have also equal *total* pressures; as the back and friction pressures are constant quantities; and as, leaving out of consideration the slight increase of dynamic effect due to increased temperature in the higher pressures, any numbers which express the comparative economy of different measures of expansion in rapport of *total* power are independent of the initial pressure of the steam; they express also the comparative economy of the same measures of expansion in rapport of *net* power, when equal mean pressures are maintained during the different degrees of expansion. The numbers, therefore, in line 21 express the comparative economy of the different measures of expansion employed in the experiments when the same engine is used to exert the same power, but with increased initial pressure with each increase in the degree of expansion.

*Modification of Power.*—The economic efficiency of any given engine is greatest when using its maximum mean total pressure; because then it has both the advantages of the greater dilatation due to the higher temperatures and the greater proportion of *net* to *total* pressure. In most applications of the steam engine, however, it is necessary to sometimes use considerably less than the maximum power, and it becomes a question of considerable importance to know how to do it with the least loss of economical efficiency. There are three modes in common use for reducing the power of the engine below the maximum, as follows: 1st, By reducing the boiler pressure; 2d, By partially closing the throttle valve and maintaining the same boiler pressure; and, 3d, By suppressing the steam at an earlier portion of the stroke by means of an adjustable cut-off and maintaining the same boiler pressure.

The impression obtains very generally among engineers, that the second of these plans is a decided improvement upon the first, and that the third is a still more decided improvement upon the second.

The first method reduces the mean pressure without any change whatever in the degree of expansion. The third does it entirely by increasing the measure of expansion, and the second may be said to be a compromise between the other two methods. Now, it happens, fortunately, that the foregoing table furnishes all the necessary experimental quantities required for determining the relative economy of the first and third methods, and as the second falls between these two, it will hereafter be seen that it is not important to know its exact economy.

The first three and the fifth lines in the following table are taken from the foregoing general table. Line 1 represents the total pressures, line 2 the net pressures, and line 3 the per centum which the latter are of the former. These last quantities represent the relative net power that would be obtained per unit of weight of fuel when using the steam with the same measure of expansion, but with the different net pressures on line 2; and by dividing unity by each of them we obtain a new set of quantities that show the relative cost in fuel of the unit of net power. Then, calling the one unity which falls into the column headed $\frac{1}{10}$ (that being the point recommended for permanently cutting off the steam), we obtain the proportional quantities on line 4,

which represent the comparative cost of the power when maintaining the same degree of expansion, and changing the net pressures to those found in the other columns on line 2 by varying the boiler pressure.

The quantities on line 5 are those on line 22 of the general table, but arranged for unity in the column headed $\frac{7}{10}$, instead of that headed $\frac{11}{12}$, and show the comparative economy of changing the net pressures to those found in the other columns on line 2 by retaining the same initial pressure and varying the measure of expansion.

The differences between the respective quantities on these two lines are given on line 6, and represent the per centum of loss or gain experienced by avoiding a complicated piece of mechanism, and reducing the power by merely reducing the boiler pressure without the assistance of any mechanism whatever.

| | Fraction of the Stroke Completed when the Steam was Cut Off. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{11}{12}$ | $\frac{7}{10}$ | $\frac{4}{9}$ | $\frac{3}{10}$ | $\frac{1}{4}$ | $\frac{1}{6}$ | $\frac{4}{45}$ |
| 1 | 34·0 | 31·1 | 27·1 | 22·9 | 20·1 | 16·4 | 12·5 |
| 2 | 29·2 | 26·3 | 22·3 | 18·1 | 15·3 | 11·6 | 7·7 |
| 3 | 85·9 | 84·6 | 82·3 | 79 0 | 76·1 | 70·7 | 61·6 |
| 4 | 0·985 | 1·000 | 1·027 | 1·061 | 1·111 | 1·196 | 1·373 |
| 5 | 1·116 | 1·000 | 0·978 | 1·059 | 1·073 | 1·188 | 1·442 |
| 6 | Gain, 13·1. | | Loss, 4·9. | Loss, 0·2. | Loss, 3·8. | Loss, 0·8. | Gain, 6·9. |

It will readily be perceived that for greater measures of expansion than that obtained by cutting off at $\frac{7}{10}$, there is really no practical difference in the economy of the two methods; and as the use of the throttle valve, the most convenient of the three plans, comes between the other two in its economic efficiency, it may be considered as neither more nor less economical than the adjustable cut-off, but has the decided advantage of being extremely simple in its construction and convenient to manage.

*Loss by clearance in the Cylinder.*—There is a loss of useful effect in every steam engine by being required to fill the *clearance* at every stroke; and the per centum of this loss is different with different measures of expansion. An examination of the subject will tend to explain in part why we do not obtain in practice the whole benefit promised by the theory of expansion.

When the engine is working full stroke, the per centum of loss is exactly equal to that which the amount of space comprised in the clearance, is of the whole space filled with steam per stroke. In the case of using steam expansively, however, this ratio is modified; a part of the steam in the clearance producing a dynamic effect during expansion, and on the other hand, the space comprised in the clearance being constant, the shorter the steam is cut off the greater becomes the ratio which this space bears to that filled with steam before the valve closes.

To ascertain the per centum of loss experienced from this cause, it is necessary to imagine an engine running without any clearance what-

ever, and to compare its economy with that experimented upon. The results of such a comparison are given in the following table. Line 1 contains the effective pressures in pounds per square inch on the piston according to the law of Mariotte under the experimental conditions. Line 2 contains what would have been the net effective pressures according to the same law had there been no clearance and had the same amount of steam been admitted to the cylinder per stroke; in which case the measures of expansion would have been correspondingly lessened. Line 3 contains the difference between the quantities on lines 1 and 2. Line 4 contains the per centums which the quantities on line 3 are of those on line 2.

| | Fraction of the Stroke Completed when the Steam was Cut Off. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{11}{12}$ | $\frac{7}{10}$ | $\frac{4}{9}$ | $\frac{3}{10}$ | $\frac{1}{4}$ | $\frac{1}{6}$ | $\frac{4}{45}$ |
| 1 | 29·7 | 26·5 | 22·8 | 18·3 | 16·4 | 12·4 | 7·8 |
| 2 | 29·9 | 26·9 | 23·9 | 19·8 | 17·8 | 14·1 | 9·1 |
| 3 | 0·2 | 0·4 | 1·1 | 1·5 | 1·4 | 1·7 | 1·3 |
| 4 | 0·07 | 1·49 | 4·60 | 7·58 | 7·86 | 12·06 | 14·29 |

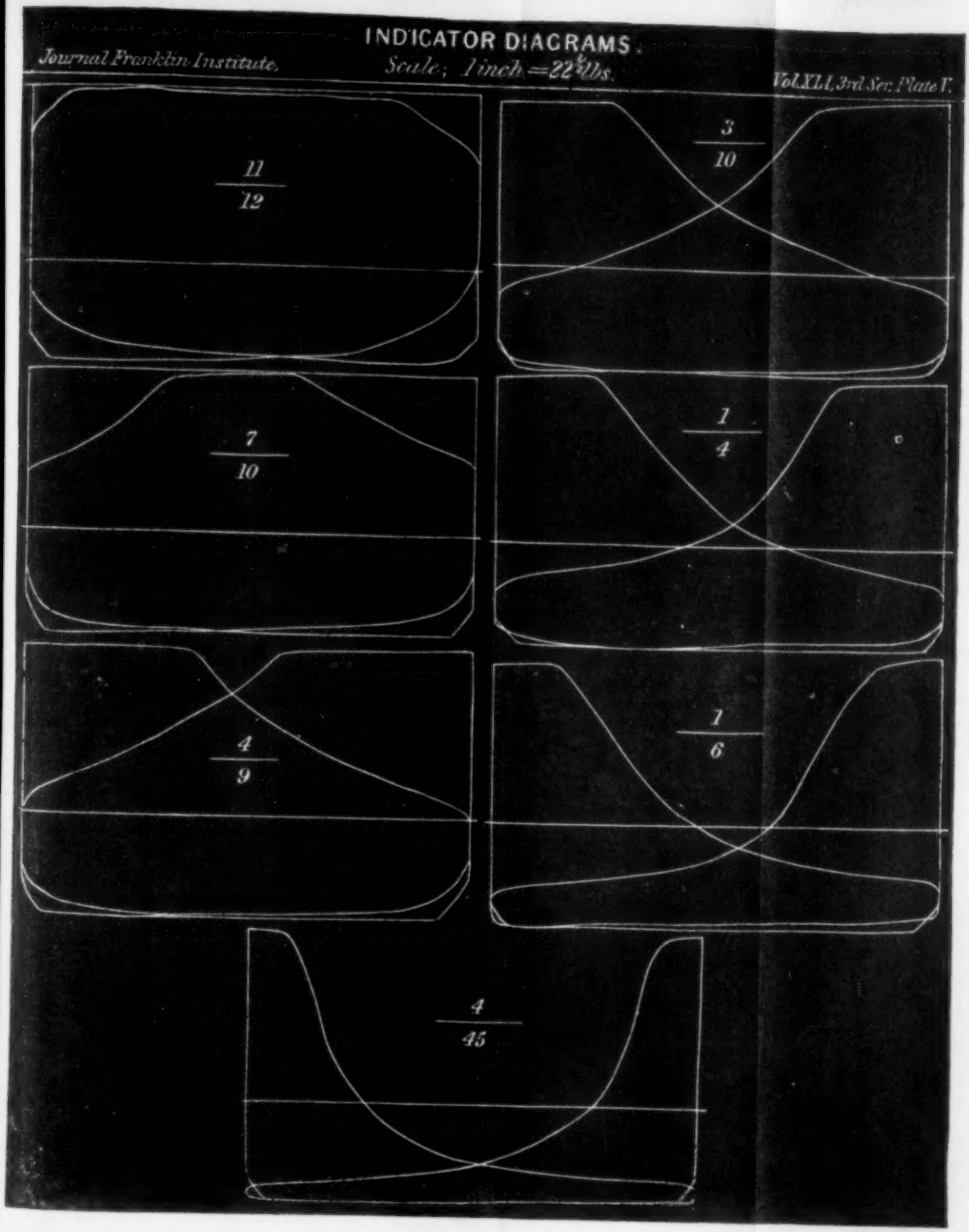
An inspection of line 4 of the above table will show how rapidly the loss due to clearance increases with the measure of expansion.

*Condensation in the Cylinder.*—A comparison of the quantities on line 25 of the general table, will give at once a correct impression of the principal cause why we do not obtain in practice any approach to the gain promised by the theory when using steam expansively. The discrepancy between the indicator and tank measurements of the water evaporated it will be observed, is very small, only 2·91 per centum, when cutting off at $\frac{11}{12}$, but rapidly increases to the enormous amount of 33·07 per centum, when cutting off at $\frac{3}{10}$, and this is considered as using expansion very moderately. In the 2·91 per centum is included every kind of leakage, and the condensation due to radiation of heat from the steam-pipe, steam-chests, and cylinder, and as the loss from these causes was necessarily constant during all the experiments, it was evidently too small to be considered. Condensation within the cylinder due to the varying temperatures and pressures occurring therein at every stroke of the piston, is the only explanation which can be given; and the only accepted law of physics which could cause the condensation, requires that the surfaces with which the inflowing steam comes in contact, should be cooler than itself; the condensation taking place upon those surfaces.

The surfaces of the cylinder are cooled down below the temperature of the steam of initial pressure, partly by being in contact during a portion of each double stroke of the piston with vapor of less temperature than that to which they have been raised by the steam of initial pressure, but if we consider the slowness with which steam already formed receives additional heat, and the small amount required to elevate the temperature of that in immediate contact with the surfaces to equilibrium, it will become evident to us that this cause is hardly worth considering.

# INDICATOR DIAGRAMS.

Scale; 1 inch = 22½ lbs.



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There is, however, a powerful cooling influence, entirely independdent of the varying *temperatures*, and dependent only upon the varying *pressures*. It is that of evaporation from the surfaces. Let us suppose that the engine is running full stroke, and that when the steam enters the cylinder at the commencement of the stroke, the surfaces with which it comes in contact are slightly cooler than itself; condensation of a portion of the steam upon those surfaces is the only manner in which the metal can be heated to an equilibrium by the steam. They become therefore immediately covered with a dew-like film of water. This water retains the same *temperature* as that of the steam with which it is in contact, and which it would itself have shown before its condensation, the *latent heat* only of the vapor condensed, entering the metal of the cylinder. Further, when the piston commences to move, it exposes to contact with the steam, the concave surface of the cylinder which had just previously been exposed to the lower pressure and temperature on the other side, and condensation takes place upon this surface as it is uncovered by the piston throughout the stroke, so that when the piston has arrived at the end of the stroke and the cylinder is full of steam of initial pressure and temperature, its whole interior surface is covered with a thin film of water at exactly the boiling point due to that pressure. When the exhaust valve opens and the pressure falls to that of the back pressure, the temperature necessary for water to boil, falls with it. In the case of the experiments, the temperature of the water condensed under the pressure of the entering steam, was 120° Fahr. higher than the boiling point of water under the back pressure. This water, therefore, immediately evaporates, converting into the latent heat of the vapor formed, not only the surplus temperature contained within itself, but also that which had been imparted to the metal of the cylinder at the time of its condensation. In this case all the heat thus robbed from the cylinder, and which must be returned to it by a new condensation at the next stroke, goes off to the condenser and is a total loss.

In the case, however, of using steam expansively, this is modified; for, as soon as the cut-off valve has closed, the pressure commences to fall, and, although condensation upon the surfaces continually exposed by the piston still goes on, as in the case of maintaining the initial pressure to the end of the stroke, the water which had been condensed under the higher pressure commences to evaporate as soon as this pressure commences to fall; and this re-evaporation goes on throughout the remainder of the stroke of the piston, so that the whole interior of the cylinder upon the steam side of the piston is being cooled down by evaporation from its surfaces, from the moment the cut-off valve is closed until the steam is again admitted to that side of the piston. The steam resulting from this re-evaporation before the end of the stroke is measured, of course, by the indicator, and is not accounted for by the quantities on line 25 of the table; and as during that portion of the stroke which was made by the piston while each particle existed in the form of water, such particle did not exert any dynamic force; the loss in dynamic effect due to condensation within the cylin-

der is greater than is measured by its amount as given in the table; but not so great as is due to the total quantity therein condensed, which quantity was not determined by these experiments.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamer Wm. G. Hewes.*

Hull built by Harlan, Hollingsworth & Co., Wilmington, Del. Machinery by Morgan Iron Works, New York. Owner, Charles Morgan. Intended service, New York to Galveston.

HULL.—Length on deck, 239 ft. 4 ins. Do. at load line, 234 ft. Breadth of beam (molded), 33 feet. Depth of hold, 10 ft. Do. to spar deck, 18 ft. Length of engine room, 76 ft. Frames—molded, 4 ins., sided, 1 in.—apart at centres, 16 ins. Sketch of shape, |; depth, 4 ins. 16 strakes of plates from keel to gunwale; thickness of plates, ½ to 11-16 in. Description of cross floors, ⅂, 18 ins. deep, 9-16 and ½ in. thick. Depth of keel, 6 ins. Diameter of rivets, ¾ in.; double riveted. One independent steam, fire, and bilge pump. 3 bulkheads. 10 fore and aft keelsons, 18 ins. high ⊤. Cabin on deck. Draft, forward and aft, 9 feet. Tonnage, 1477·45. Area of immersed section at load draft of 9 feet, 270 sq. feet. Displacement at load line, 1253 tons. Masts, two.—Rig, schooner.

ENGINE.—Vertical beam. Diameter of cylinder, 50 ins. Length of stroke, 11 feet. Maximum pressure of steam, 30 lbs. Cut off at half stroke. Maximum revolutions at above pressure, 18. Weight of engines, 190,000 lbs.

BOILER.—One—Return tubular, and of steel plates. Length of boiler, 21 ft. Breadth do., 17 feet. Height do., exclusive of steam chimney, 9 feet. Weight do., with water, 102,690 lbs. Number of furnaces, four. Breadth of do., 3 ft. 6 ins. Length of grate bars, 6 ft. 8 ins. Number of tubes, above, 92; flues, below, 8. Internal diameter of tubes, above, 5 ins.; flues, below, 19 ins. Length of tubes, above, 15 ft.; flues, below, 11 ft. 4 ins. Grate surface, 93·09 sq. ft. Heating surface, 2600 sq. ft. Diameter of smoke pipe, 5 ft. 8 ins. Height of do., above grates, 50 feet. Consumption of fuel per hour, 1680 lbs.

PADDLE WHEELS.—Diameter over boards, 30 ft. Length of blades, 7 ft. 6 ins. Depth, do., 20 ins. Number do., 26.

Date of trial, December, 1860. C. H. H.

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For the Journal of the Franklin Institute.

## *Particulars of the Pilot Boat Wm. H. Aspinwall.*

Hull built by Messrs. J. D. & J. B. Van Deusen, foot of Sixteenth Street, East River, New York. Owners, Messrs. Geo. Berger, John N. Dale, Gideon Mapes, Wm. A. Anderson, and Capt. Walter Brewer,—all New York pilots. Intended service, Harbor of New York.

HULL.—Length of keel, 74 feet. Do. on deck, 80 ft. Breadth of beam, 19 ft. 6 ins. Depth of hold, 8 ft. 9 ins. Draft, forward, 6 feet; aft, 9 ft. 6 ins. Keel, 22 ins. deep; also, a rocking keel of 12 ins. Tonnage, 100 tons.

MASTS.—Length of fore-mast, 76 feet. Do. main mast, 77 feet. Do. main boom, 46 feet. Do. fore gaff, 20 feet. Do. main gaff, 21 feet.

*Remarks.*—The *Wm. H. Aspinwall* cost $8000. Her cabin is

handsomely finished in hard wood, with maple, satin-wood, rose-wood, and black walnut, and has six enclosed berths and two state-rooms. In addition to these features, there are pantries and refrigerators in the run, steward's pantry, water tank, and coal bunkers, amidships. The forward cabin is beautifully grained in oak, contains six berths, and a commodious caboose for the necessary culinary manipulations of the sailors' friend, the "Doctor." This vessel has a sheer on deck of three feet, which gives her a very graceful and buoyant appearance as she sits on the water.

The New York pilot boats are distinguished the world over for swiftness and great beauty of model. They have furnished in many instances the original models for the very swiftest of American yachts, the reputation of which is unrivalled, and spreads far and wide. Great rivalry, consequently, exists between our respective ship-builders to excel in constructing the best and swiftest of such craft, as a successful boat of this character attracts no inconsiderable degree of interest amongst not only those directly interested, but the public generally.

Upon a late run of 50 miles by the *Wm. H. Aspinwall*, her sailing qualities, obedience to the helm in steering, &c., &c., were variously noticed and considered eminently satisfactory by all on board, there being amongst the number many who were qualified to judge. We have no doubt her future performances will reflect still greater credit on her builders. E. B.

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*United States Patent Law. An Act in addition to an "Act to promote the progress of the Useful Arts." Approved March 2d*, 1861.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Commissioner of Patents may establish rules for taking affidavits and depositions required in cases pending in the Patent Office, and such affidavits and depositions may be taken before any justice of peace, or other officer authorized by law to take depositions to be used in the courts of the United States, or in the State courts of any State where such officer shall reside; and in any contested case pending in the Patent Office it shall be lawful for the clerk of any court of the United States, for any District or Territory, and he is hereby required, upon the application of any party to such contested case, or the agent or attorney of such party, to issue subpœnas for any witnesses residing or being within the said district or territory, commanding such witnesses to appear and testify before any justice of the peace, or other officer as aforesaid, residing within the said district or territory, at any time and place in the subpœna to be stated; and if any witness, after being duly served with such subpœna, shall refuse or neglect to appear, or, after appearing, shall refuse to testify, (not being privileged from giving testimony,) such refusal or neglect being proved to the satisfaction of any judge of the court whose clerk shall have issued such subpœna, said judge may thereupon proceed to enforce obedience to the process, or to punish the disobedience in like manner as any court of the United States may do in case of disobedience to process of subpœna ad testificandum is-

sued by such court; and witnesses in such cases shall be allowed the same compensation as is allowed to witnesses attending the courts of the United States; *Provided*, That no witness shall be required to attend at any place more than forty miles from the place where the subpœna shall be served upon him, to give a deposition under this law: *Provided also*, That no witness shall be deemed guilty of contempt for refusing to disclose any secret invention made or owned by him: *And provided further*, That no witness shall be deemed guilty of contempt for disobeying any subpœna directed to him by virtue of this act, unless his fees for going to, returning from, and one day's attendance at the place of examination shall be paid or tendered to him at the time of the service of the subpœna.

SECTION 2. *And be it further enacted*, That, for the purpose of securing greater uniformity of action in the grant and refusal of letters patent, there shall be appointed by the President, by and with the advice and consent of the Senate, three examiners-in-chief, at an annual salary of three thousand dollars each, to be composed of persons of competent legal knowledge and scientific ability, whose duty it shall be, on the written petition of the applicant for that purpose being filed, to revise and determine upon the validity of decisions made by examiners when adverse to the grant of letters patent; and also to revise and determine in like manner upon the validity of the decisions of examiners in interference cases, and when required by the commissioner in applications for the extension of patents, and to perform such other duties as may be assigned to them by the commissioner; that from their decisions appeals may be taken to the Commissioner of Patents in person, upon payment of the fee hereinafter prescribed; that the said examiners-in-chief shall be governed in their actions by the rules to be prescribed by the Commissioner of Patents.

SECTION 3. *And be it further enacted*, That no appeal shall be allowed to the examiners-in-chief from the decisions of the primary examiners, except in interference cases, until after the application shall have been twice rejected; and the second examination of the application by the primary examiner shall not be had until the applicant, in view of the reference given on the first rejection, shall have renewed the oath of invention, as provided for in the seventh section of the act entitled "An act to promote the progress of the useful arts, and to repeal all acts and parts of acts heretofore made for that purpose," approved July fourth, eighteen hundred and thirty-six.

SECTION 4. *And be it further enacted*, That the salary of the Commissioner of Patents, from and after the passage of this act, shall be four thousand five hundred dollars per annum, and the salary of the chief clerk of the Patent Office shall be two thousand five hundred dollars, and the salary of the librarian of the Patent Office shall be eighteen hundred dollars.

SECTION 5. *And be it further enacted*, That the Commissioner of Patents is authorized to restore to the respective applicants, or when not removed by them, to otherwise dispose of such of the models belonging to rejected applications as he shall not think necessary to be preserved. The same authority is also given in relation to all models

accompanying applications for designs. He is further authorized to dispense in future with models of designs when the design can be sufficiciently represented by a drawing.

SECTION 6. *And be it further enacted*, That the tenth section of the act approved the third of March, eighteen hundred and thirty-seven, authorizing the appointment of agents for the transportation of models and specimens to the Patent Office, is hereby repealed.

SECTION 7. *And be it further enacted*, That the Commissioner is further authorized, from time to time, to appoint, in the manner already provided for by law, such an additional number of principal examiners, first assistant examiners, and second assistant examiners, as may be required to transact the current business of the office with despatch, provided the whole number of additional examiners shall not exceed four of each class, and that the total annual expenses of the Patent Office shall not exceed the annual receipts.

SECTION 8. *And be it further enacted*, That the Commissioner may require all papers filed in the Patent Office, if not correctly, legibly, and clearly written, to be printed at the cost of the parties filing such papers; and for gross misconduct he may refuse to recognise any person as a patent agent, either generally or in any particular case; but the reasons of the Commissioner for such refusal shall be duly recorded, and subject to the approval of the President of the United States.

SECTION 9. *And be it further enacted*, That no money paid as a fee on any application for a patent after the passage of this act shall be withdrawn or refunded, nor shall the fee paid on filing a caveat be considered as part of the sum required to be paid on filing a subsequent application for a patent for the same invention.

That the three months' notice given to any caveator, in pursuance of the requirements of the twelfth section of the act of July fourth, eighteen hundred and thirty-six, shall be computed from the day on which such notice is deposited in the post-office at Washington, with the regular time for the transmission of the same added thereto, which time shall be endorsed on the notice; and that so much of the thirteenth section of the act of Congress, approved July fourth, eighteen hundred and thirty-six, as authorizes the annexing to letters patent of the description and specification of additional improvements, is hereby repealed, and in all cases where additional improvements would now be admissible, independent patents must be applied for.

SECTION 10. *And be it further enacted*, That all laws now in force, fixing the rates of the Patent Office fees to be paid, and discriminating between the inhabitants of the United States and those of other countries, which shall not discriminate against the inhabitants of the United States, are hereby repealed, and in their stead the following rates are established:—

On filing each caveat, ten dollars.

On filing each original application for a patent, except for a design, fifteen dollars.

On issuing each original patent, twenty dollars.

On every appeal from the Examiners-in-Chief to the Commissioner, twenty dollars.

On every application for the re-issue of a patent, thirty dollars.

On every application for the extension of a patent, fifty dollars; and fifty dollars, in addition, on the granting of every extension.

On filing each disclaimer, ten dollars.

For certified copies of patents, and other papers, ten cents per hundred words.

For recording every assignment, agreement, power of attorney, and other papers of three hundred words or under, one dollar.

For recording every assignment, and other papers, over three hundred and under one thousand words, two dollars.

For recording every assignment or other writing, if over one thousand words, three dollars.

For copies of drawings, the reasonable cost of making the same.

* SECTION 11. *And be it further enacted*, That any citizen or citizens, or alien or aliens, having resided one year in the United States and taken the oath of his or their intention to become a citizen or citizens, who by his, her, or their own industry, genius, efforts, and expense, may have invented or produced any new and original design for a manufacture, whether of metal or other material or materials, and original design for a bust, statue, or bas relief, or composition in alto or basso relievo, or any new and original impression or ornament, (or) to be placed on any article of manufacture, the same being formed in marble or other material, or any new and useful pattern, or print, or picture, to be either worked into or worked on, or printed, or painted, or cast, or otherwise fixed on any article of manufacture, or any new and original shape or configuration of any article of manufacture, not known or used by others before his, her, or their invention or production thereof, and prior to the time of his, her, or their application for a patent therefor, and who shall desire to obtain an exclusive property or right therein to make, use, (and sell) and vend the same, or copies of the same, to others, by them to be made, used, and sold, may make application in writing, to the Commissioner of Patents, expressing such desire: and the Commissioner, on due proceedings had, may grant a patent therefor, as in the case now of application for a patent, for the term of three and one-half years, or for the term of seven years, or for the term of fourteen years, as the said applicant may elect in his application: *Provided*, That the fee to be paid in such application shall be, for the term of three years and six months, ten dollars; for seven years, fifteen dollars; and for fourteen years, thirty dollars: *And provided*, That the patentees of designs under this act shall be entitled to the extension of their respective patents, for the term of seven years from the day on which said patents shall expire, upon the same terms and restrictions as are now provided for the extension of letters patent.

SECTION 12. *And be it further enacted*, That all applications for patents shall be completed and prepared for examination within two years after the filing of the petition, and in default thereof, they shall

*This section of the Act originated with, and was drawn up by Mr. H. Howson of this city, whose communication on the subject was published in this Journal, Vol. xxxix, 3d Series, page 265 .

be regarded as abandoned by the parties thereto, unless it be shown to the satisfaction of the Commissioner of Patents that such delay was unavoidable; and all applications now pending shall be treated as if filed after the passage of this act; and all applications for the extension of patents shall be filed at least ninety days before the expiration thereof, and notice of the day set for the hearing of the case shall be published, as now required by law, for at least sixty days.

SECTION 13. *And be it further enacted*, That in all cases where an article is made or vended by any person under the protection of letters patent, it shall be the duty of such person to give sufficient notice to the public that said article is so patented, either by affixing thereon the word patented, together with the day and year the patent was granted, or when, from the character of the article patented, that may be impracticable, by enveloping one or more of the said articles, and affixing a label to the package, or otherwise attaching thereto a label on which the notice, with the date, is printed; on failure of which, in any suit for the infringement of letters patent by the party failing so to mark the article the right to which is infringed upon, no damage shall be recovered by the plaintiff, except on proof that the defendant was duly notified of the infringement, and continued after such notice to make or vend the article patented. And the sixth section of the act entitled an "Act in addition to an act to promote the progress of the useful arts," and so forth, approved the twenty-ninth day of August, eighteen hundred and forty-two, be, and the same is hereby, repealed.

SECTION 14. *And be it further enacted*, That the Commissioner of Patents be, and he is hereby, authorized to print, or in his discretion to cause to be printed, ten copies of the description and claims of all patents which may hereafter be granted, and ten copies of the drawings of the same, when drawings shall accompany the patents: *Provided*, The cost of printing the text of said descriptions and claims shall not exceed, exclusive of stationery, the sum of two cents per hundred words for each of the said copies, and the cost of the drawing shall not exceed fifty cents per copy: one copy of the above number shall be printed on parchment, to be affixed to the letters patent: the work shall be under the direction, and subject to the approval, of the Commissioner of Patents, and the expense of the said copies shall be paid for out of the Patent Fund.

SECTION 15. *And be it further enacted*, That printed copies of the letters patent of the United States, with the seal of the Patent Office affixed thereto, and certified and signed by the Commissioner of Patents, shall be legal evidence of the contents of said letters patent in all cases.

SECTION 16. *And be it further enacted*, That all patents hereafter granted shall remain in force for the term of seventeen years from the date of issue; and all extensions of such patents is hereby prohibited.

SECTION 17. *And be it further enacted*, That all acts and parts of acts heretofore passed, which are inconsistent with the provisions of this act, be, and the same are hereby repealed.

## *On a new Resistance Thermometer.*—By C. William Siemens.

From the Lond. Ed. and Dub. Phil. Mag., Jan., 1861.

To Professor John Tyndall, F. R. S., &c., Royal Institution.

My Dear Sir,—You will probably be interested to hear about a very direct application of physical science to a purpose of considerable practical importance, which I had lately occasion to make. Having charge, for the British Government, of the Rangoon and Singapore telegraph cable, in so far as its electrical conditions are concerned, I was desirous to know the precise temperature of the coil of cable on board ship at different points throughout its mass, having been led by previous observations to apprehend spontaneous generation of heat. As it would have been impossible to introduce mercury thermometers into the interior of the mass, I thought of having recourse to an instrument based upon the well-ascertained fact that the conductivity of a copper wire increases in a simple ratio inversely with its temperature. The instrument consists of a rod or tube of metal about 18 inches long, upon which silk-covered copper wire is wound in several layers so as to produce a total resistance of, say 1000 (Siemens) units at the freezing temperature of water. The wire is covered for protection with sheet india rubber, inserted into a tube and hermetically sealed. The two ends of the coil of wire are brought, by means of insulated conducting wires, into the observatory, where they are connected to measuring apparatus, consisting of a battery, galvanometer, and variable resistance coil. The galvanometer employed has two sets of coils, traversed in opposite directions by the current of the battery. One circuit is completed by the insulated thermometer coil, and the other by a variable resistance coil of German silver wire. Instead of the differential galvanometer, a regular Wheatstone's bridge arrangement may be employed.

You will readily perceive that if the thermometer coil before described were placed in snow and water, and the variable resistance coil were stoppered so as to present 1000 units of resistance, the currents passing through both coils of the differential galvanometer would equal one another, and produce, therefore, no deflection of the needle. If, however, the temperature of the water should rise, say 1° Fahr., its resistance would undergo an increase $1000 \times \cdot 0021 = 2 \cdot 1$ units of resistance, necessitating an addition of 2·1 units to the variable resistance coil in order to re-establish the equilibrium of the needle.

The ratio of increase of resistance of copper wire with increase of temperature may be regarded as perfectly constant within the ordinary limits of temperature; and being able to appreciate the tenth part of a unit in the variable resistance coil employed, I have the means of determining with great accuracy the temperature of the locality where the thermometer resistance coil is placed. Such thermometer resistance coils I caused to be placed between the layers of the cable at regular intervals, connecting all of them with the same measuring apparatus in the cabin.

After the cable had been about ten days on board (having left a

wet tank on the contractors' works), very marked effects of heat resulted from the indications of the thermometer coils inserted into the interior of the mass of the cable, although the coils nearer the top and bottom surfaces did not show yet any remarkable excess over the temperature of the ship's hold, which was at 60° Fahr. The increase of heat in the interior progressed steadily at the rate of about 3° Fahr. per day, and having reached 86° Fahr., the cable would have been inevitably destroyed in the course of a few days, if the generation of heat had been allowed to continue unchecked.

Considering the comparatively low temperature of the surface of the cable, much incredulity was expressed by lookers-on, respecting the trust-worthiness of these results; but all doubts speedily vanished when large quantities of cold water of 42° temperature were pumped upon the cable, and found to issue 72° Fahr. at the bottom.

Resistance thermometers of this description might, I think, be used with advantage in a variety of scientific observations,—for instance, to determine the temperature of the ground at various depths throughout the year, or of the sea at various depths, &c., &c. In the construction of this instrument, care has to be taken that no sensible amount of heat is generated by the galvanic currents in any of the resistances employed.

By substituting an open coil of platinum wire for the insulated copper coil, this instrument would be found useful also as a pyrometer.

But finding this letter already exceeds its intended limits I shall not enlarge upon these applications, which, no doubt, are quite obvious to you. I am, &c.

December, 1860.

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### *French Steam Frigate "La Gloire."*

This is the first steam vessel which was sheathed with iron. It is a magnificent ship, 77 metres (252·74 ft.) long, by 15 metres (49·23 ft.) wide, owing an imposing appearance to the severity of her lines, and her massive cuirass. At a height of 1·82 metres (6 ft.) above the water-line is a battery of 12 heavy guns. Her quarter-deck is fortified with iron, to insure the commander's post. In a quiet sea *La Gloire* divides the water without shock, and so to speak without foam. She has reached a speed of 13·21 knots, with all furnaces lighted; 11 knots, with half furnaces. In a heavy sea she parts the waves with very little pitching, and with a quartering wave, the ease of her roll leaves nothing to be desired.—*Cosmos*, November, 1860.

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## AMERICAN PATENTS.

AMERICAN PATENTS ISSUED FROM JANUARY 1, TO JANUARY 31, 1861.

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| Adding Machines, | Joseph Harris, Jr., | Roxbury, | Mass. | 1 |
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| Anchor Well and Anchor, | Ross and Thos. Winans, | Baltimore, | Md. | 29 |
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| Axles,—Railroad Car | A. E. Smith, | Brouxville, | " | 8 |
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| Baskets,—Manufacture of | Thomas Hegarty, | St. Louis, | Mo. | 15 |
| Bed Bottom,—Spring | H. L. Thistle, | City of | N. Y. | 22 |
| Blacking Box Holder, | J. W. Lewis, | Providence, | R. I. | 1 |
| Bonnets,—Pressing | H. E. West, | Attleborough, | Mass. | 29 |
| Boot Legs,—Turning | A. Ransom, | Manheim, | N. Y. | 29 |
| Bottles,—Glass Stopper for | S. A. Whitney, | Glassborough, | N. J. | 1 |
| Bed Bottom, | J. S. Smith, | Lowell, | Mass. | 29 |
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| Brakes,—Adjustable Carriage | J. A. Letts, | Trumansburg, | N. Y. | 29 |
| ———,—Automatic | John Wilkinson, | Baltimore, | Md. | 1 |
| ———,—Car | W. C. Wright, | City of | N. Y. | 15 |
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| Brick Tiles, &c.,—Making | E. G. Oldfield, | Bordentown, | N. J. | 15 |
| Bridges,—Iron | Lewis Eikenberry, | Easton, | Penna. | 22 |
| Candle Wicks, | C. A. Wortendyke, | Godwinville, | N. J. | 1 |
| Caoutchouc,—Compositions of | R. F. H. Havemann, | N. Brunswick, | " | 29 |
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| Carpenters,—Machine for | Wm. R. Axe, | Beloit, | Wis. | 22 |
| Carriage Bodies,—Hanging | Stringfellow & Surles, | Lumpkin, | Ga. | 15 |
| ——— Seats,—Self-adjusting | John C. Kimball, | New Haven, | Conn. | 1 |
| Carriages,—Children's | J. A. Crandall, | City of | N. Y. | 15 |
| Cars,—Stopping and Starting | James Higgin, | Manchester, | Engl'd, | 8 |
| Carts or Wagons,—Weighing | N. E. Doane, | Hannibal, | Mo. | 22 |
| Chain Cables,—Link Shackle of | W. J. Hotchkiss, | Derby, | Conn. | 1 |
| Chimney Top, | Nicholas Hackett, | Albany, | N. Y. | 1 |
| Clocks,—Winding | Robert Hitchcock, | Watertown, | " | 29 |
| Clothes Dryer, | J. H. Durand, | Niles, | Mich. | 1 |
| ——— | C. G. Sargent, | Chelsea, | Mass. | 29 |
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| Corn Planters, | A. W. Brinkerhoff, | Up. Sandusky, | Ohio, | 8 |
| ——— | Wm. Combs, | Duquoin, | Ill. | 8 |
| ——— | E. W. Kimball, | Ottawa, | " | 8 |
| ——— | J. Y. D. Murphy, | Half Moon, | Penna. | 22 |
| ——— | W. C. Willey, | Princeton, | Ill. | 22 |
| —— Shellers, | C. C. French, | W. Stockbridge, | Mass. | 15 |
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| ——— Cleaners, | E. W. Tarpley & others, | Jackson, | Miss. | 1 |
| ——— Gins, | J. E. Ferguson, | Micanopy, | Fa. | 1 |
| ——— Pickers, | John Griffin, | Louisville, | Ky. | 22 |
| ——— Scrapers, | J. D. Houston, | Pope's Depot, | Miss. | 15 |
| Couplings,—Railroad Car | Osgood & Shaw, | Boston, | Mass. | 15 |
| ——— | Archibald H. Rowand, | Allegheny, | Penna. | 1 |
| ———,—Hose | Ambrose E. Barnard, | Paterson, | N. J. | 15 |
| Cultivators, | J. T. D. Alexander, | Maryenna, | Texas, | 15 |
| ——— | W. A. Dryden, | Monmouth, | Ill. | 15 |
| ——— | E. W. Fuller, | Martinsville, | La. | 22 |
| ——— | A. B. Lefler, | Canton, | Ind. | 22 |
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| Curry Combs,—Riveting | B. B. Hotchkiss, | Sharon, | Conn. | 1 |
| ——— | Sarah Jane Wheeler, | New Britain, | " | 22 |
| Curtain Fixture, | E. M. Judd, | " | " | 29 |
| Cutting and Grinding Apparatus, | Purches Miles, | New Haven, | " | 8 |
| Deck Light, | Henry Lanergan, | E. Cambridge, | Mass. | 29 |
| Docking Ships, &c.,—Appa's for | J. W. Nystrom, | St. Petersburg, | Russia, | 15 |
| Dough,—Mixing | Wm. Hotine, | Brooklyn, | N. Y. | 8 |
| Dove-tailing Machine, | King & Norris, | Lexington, | Ky. | 22 |

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| Draw-bridges, | Bayley & Nelson, | Brashear, | La. | 29 |
| Drawer Alarms, | F. H. Purington, | Willimantic, | Conn. | 22 |
| Evaporating Liquids, | Hathaway & Lathrop, | Detroit, | Mich. | 1 |
| Fabrics Air and Water Tight, | A. C. Teubner, | City of | N. Y. | 22 |
| Fare Boxes, | W. B. Bartram, | Norwalk, | Conn. | 22 |
| ——— | J. B. Slawson, | New Orleans, | La. | 29 |
| Fertilizers,—Sowing | John F. Killer, | Greencastle, | Penna. | 1 |
| Fibrous Material,—Reducing | Reuben Daniels, | Woodstock, | Vt. | 22 |
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| Fire Arms,—Breech-loading | Frederick Townsend, | Albany, | N. Y. | 29 |
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| ——— | J. W. Sprague, | Rochester, | " | 22 |
| —— Places, | John McMurtry, | Fayette co., | Ky. | 22 |
| Gaiters,—Ankle-supporting | T. G. Rich, | Milton, | Mass. | 29 |
| Gas Regulators, | C. L. Herring, | St. Louis, | Mo. | 22 |
| Glass Making,—Pots for | Edward Dithridge, | Pittsburgh, | Penna. | 1 |
| Grain Dryers, | Samuel Schuyler, | Brooklyn, | N. Y. | 22 |
| —— Separators, | A. Fanckboner, | Schoolcraft, | Mich. | 15 |
| ——— | Ellis Michael, | La Porte, | Ind. | 8 |
| Gymnastic Apparatuses, | Veerkamp & Leopold, | Philadelphia, | Penna. | 1 |
| Hair Crimpers, | W. F. George, | City of | N. Y. | 29 |
| Hat Bodies,—Making | J. F. Greene, | Brooklyn, | " | 1 |
| Hats,—Finishing | J. H. La Bau, | City of | " | 22 |
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| ——— | D. S. Morgan, | Brockport, | N. Y. | 22 |
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| ——— | Lewis Miller, | " | " | 29 |
| Hay,—Machines for Gathering | F. F. Fowler, | Crane towns'p, | " | 22 |
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| ——— | McCormick & Baker, | " | " | 22 |
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| ——— Devices, | J. J. Doyle, | City of | " | 8 |
| Hollow Ware,—Boiled Metallic | Ezra Ripley, | Troy, | " | 1 |
| Horse Powers, | Gelston Sanford, | City of | " | 8 |
| Horses from Interfering, | D. G. Kettell, | Worcester, | Mass. | 22 |
| ———,—Harness for Shoeing | J. P. Reynolds, | Mirabile, | Mo. | 22 |
| ———,—Strap for Fastening | D. S. Bartlett, | Roxbury, | Mass. | 15 |
| Hot Air Pipes,—Evaporator for | G. F. J. Colburn, | Newark, | N. J. | 22 |
| Hub Machines, | I. N. Felch, | Hollis, | Me. | 22 |
| Hydrometers, | James Adams, | City of | N. Y. | 15 |
| Ice Crusher, | John Middleton, | City of | N. Y. | 1 |
| Iron,—Centering Bars of | N. F. Newell, | Northbridge, | Mass. | 29 |
| ——,—Corrugating | J. S. Vernam, | Rochester, | N. Y. | 1 |
| ——,—Manufacture of Sheet | D. A. Morris, | Pittsburgh, | Penna. | 22 |
| —— Pavements,—Constructing | B. C. Smith, | Burlington, | N. J. | 8 |
| Kettle Handle, | Joseph Warner, | New Britain, | Conn. | 22 |
| Knife Cleaner, | Oliver Sweeney, | Norwich, | " | 22 |
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| ——— | John Terrell, | Philadelphia, | " | 1 |

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| Lamp or Candle Stand, . | F. A. Marshall, . | Marlborough, | Mass. | 29 |
| —— and Candle Wicks, | Stephen R. Weeden, | Providence, | R. I. | 1 |
| —— Chimneys,—Cleaning | T. B. DeForest, . | Birmingham, | Conn. | 15 |
| Lamps, . | C. H. Dolbeare, . | Boston, | Mass. | 1 |
| ——— . | O. C. Evans, . | City of | N. Y. | 22 |
| ——— . | Henry Leibert, . | Norristown, | Penna. | 1 |
| ——— . | Emil Trittin, . | Philadelphia, | " | 29 |
| ———,—Vapor . | C. B. Loveless, . | Tom's River, | N. J. | 22 |
| ——————— . | Levi Short, . | Buffalo, | N. Y. | 29 |
| Leather Straps,—Creasing, &c., | W. McK. Thorton, | Niles, | Mich. | 8 |
| Lever Escapement, . | Prosper Humbert, . | Boston, | Mass. | 1 |
| Light by Frictional Electricity, | Maurice Wesolowski, | City of | N. Y. | 29 |
| Lithographic Stones,—Mounting | G. H. Reynolds, . | " | " | 1 |
| Locks, . | Titus Powers, . | Philadelphia, | Penna. | 29 |
| ——— . | S. C. St. John, . | Edmeston, | N. Y. | 29 |
| ——— . | Linus Yale, Jr., . | Philadelphia, | Penna. | 29 |
| Looms,—Hand . | J. G. Henderson, . | | Mo. | 1 |
| ———,—Harness Motions for | B. F. Knowles, . | Providence, | R. I. | 22 |
| Lubricating Journals, Axles, &c., | C. L. Morehouse, . | Jackson, | Tenn. | 29 |
| | | | | |
| Mattress,—Floating . | Wm. Williams, . | St. Louis, | Mo. | 1 |
| Meat Cutter, . | Purches Miles, . | New Haven, | Conn. | 8 |
| Mill Gearing . | J. H. Glover, . | Glasgow, | Ky. | 8 |
| Millstones,—Dressing | H. B. Weaver, . | S. Windham, | Conn. | 15 |
| ——,—Facing & Polishing | Edmund Munson, | Utica, | N. Y. | 29 |
| Mouldings,—Cutting Wooden | A. H. Brown, . | Albany, | " | 22 |
| Moulding,—Preparing Patterns | Hanson Wright, | Westford, | " | 1 |
| | | | | |
| Neck Ties, . | P. F. Smith, . | City of | N. Y. | 29 |
| Needles, . | George Cooper, . | Thompsonville, | Conn. | 22 |
| Newspaper Files, . | H. S. White, . | Newport, | R. I. | 22 |
| Nut Machines, . | Purches Miles, . | New Haven, | Conn. | 1 |
| | | | | |
| Ordnance,—Breech-loading | L. C. T. Weber, . | Rochester, | N. Y. | 1 |
| ———,—Projectiles for | S. C. Abbott, . | Zanesville, | Ohio, | 15 |
| Ovens, . | Wm. Sellers, . | Philadelphia, | Penna. | 22 |
| Oxychloride of Lead, | Ludwig Brumlen, | Hoboken, | N. J. | 29 |
| | | | | |
| Paper-making Machinery, | G. J. Wheeler and others, | Bloomfield, | N. J. | 22 |
| Pavement & Railway combined, | B. C. Smith, . | Burlington, | " | 15 |
| Pencil Heads,—India Rubber | Arthur Neill, . | Boston, | Mass. | 22 |
| Penholders, . | Joel Bryant, . | Brooklyn, | N. Y. | 29 |
| Photographic Pictures,—Enlarg. | John H. Whitley, . | Owego, | " | 1 |
| Picker Staff Motion, | N. S. Bean, . | Manchester, | N. H. | 22 |
| Ploughs, . | Wm. Jarrell, . | Trenton, | Tenn. | 22 |
| ——— . | G. H. Moore, . | Rochester, | N. Y. | 1 |
| ——— . | Jeremiah Sweitzer, . | Mishawka, | Ind. | 22 |
| ——— . | Lorenz Wolfe, . | Hamburg, | Mo. | 15 |
| ———,—Covering . | Washington Roberts, | Rocheport, | " | 15 |
| —— ——,—Mole . | Homer Gillet, . | Lyndon, | Ill. | 15 |
| ———,—Seeding . | W. P. Penn, . | Belleville, | " | 15 |
| ———,—Shields to | J. F. Cameron, . | Bedford, | Mo. | 15 |
| ———,—Sub-soil . | " . | " | " | 15 |
| Preserve Cans, . | N. S. Gilbert, . | Lockport, | N. Y. | 29 |
| Presses,—Cotton . | Isaac Griffin, . | Milford, | Ga. | 8 |
| Pumps, . | Albert Bellingrath, | Atlanta, | " | 22 |
| | | | | |
| Railroad Chairs, . | E. B. Banker, . | Schaghticoke, | N. Y. | 8 |
| ——————— . | Enoch Weight, . | Charlestown, | Mass. | 29 |
| ——,—— Cars,—Stop. & Start. | Peter Louis, . | City of | N. Y. | 15 |
| ——————————— | Bernard Morohan, | Brooklyn, | " | 15 |
| ——— Stations, &c.,—Indica. | H. H. Gratz, . | Spring Station, | Ky. | 29 |
| Railway Tire,—Rolling | S. Jaqua, . | Paterson, | N. J. | 29 |
| Ranges,—Cooking . | James Ingram, . | City of | N. Y. | 8 |

| | | | | |
|---|---|---|---|---|
| Reaping Machines,—Rakes for | George Esterly, | Whitewater, | Wis. | 15 |
| Reapers,—Rakes for | M. C. Brelsford, | Girard, | Ill. | 15 |
| Refrigerator, | B. J. Burnett, | Mt. Vernon, | N. Y. | 1 |
| ——— | John C. Schooley, | Cincinnati, | Ohio, | 1 |
| Roots,—Cutting | W. C. Berry, | Woodbridge, | N. J. | 1 |
| Saccharine Juices,—Evaporating | Wm. Chesterman, | Peosta, | Iowa, | 22 |
| Sad Iron, | P. D. Van Hoesen, | City of | N. Y. | 8 |
| Sash Fastener, | Wm. B. Barnard, | Waterbury, | Conn. | 29 |
| Sausage Stuffer, | August Nettinger, Jr., | Philadelphia, | Penna. | 1 |
| Sawing Machines,—Circular | W. H. Auld, | Fairfield, | Iowa, | 22 |
| Saws,—Straining Wood | Abijah Fessenden, | Boston, | Mass. | 29 |
| ——— | James Haynes, | Hollis, | Me. | 1 |
| Saw Teeth, | I. S. Brown, | Hopkinton, | R. I. | 8 |
| Scales, | S. S. Hitchcock, | Chicago, | Ill. | 29 |
| Scissors, | John Reist, | Philadelphia, | Penna. | 1 |
| Screws,—Cutting, &c., | Bennett & Dalzell, | Waddington, | N. Y. | 22 |
| Seed Drills, | J. H. Bean, | Forreston, | Ill. | 15 |
| —— Planters,—Cotton | L. B. Brown, | Scriven co., | Ga. | 15 |
| ——— | Daniel Herlong, | Sandy Ridge, | Ala. | 15 |
| Seeding Cultivators, | Goodman & Rote, | Lancaster, | Penna. | 15 |
| ——— Machines, | C. Eggelston, | Beloit, | Wis. | 1 |
| ——— | Lee & Reese, | Phillipsburgh, | N. J. | 1 |
| ——— | David Pardee, | Carlyle, | Ill. | 8 |
| ——— | W. P. Penn, | Belleville, | " | 8 |
| ——— | W. B. Quarton, | Carlinville, | " | 8 |
| Sewing Machines, | F. D. Ballou, | Abington, | Mass. | 22 |
| ——— | J. T. Bruen, | Brooklyn, | N. Y. | 22 |
| ——— | Thomas Earle, | Worcester, | Mass. | 22 |
| ——— | Charles Irwin, | Buffalo, | N. Y. | 22 |
| ——— | Johnson & Bartlett, | Boston, | Mass. | 22 |
| ——— | S. W. Langdon, | Northampton, | " | 22 |
| ——— | Quartus Rice, | Nevada, | Cal. | 22 |
| ——— | J. C. Smith, | Troy, | N. Y. | 29 |
| ———,—Treadles | Warren Glover, | N. Eng. Village, | Mass. | 29 |
| Shingle Machines, | P. H. Woolsey, | Andes, | N. Y. | 29 |
| Shingles,—Sawing | A. F. French, | Franklin, | Vt. | 29 |
| Shoes and Boots,—Gum | Louis Bauhoefer, | Philadelphia, | Penna. | 22 |
| Shrouds of Ships,—Attaching | John Taber, | Bangor, | Me. | 1 |
| Shutters,—Rolling Iron | G. F. Letz, | Chicago, | Ill. | 29 |
| Sieves, | A. E. and J. B. Blood, | Lynn, | Mass. | 22 |
| Signalizing, | A. J. Meyer, | Buffalo, | N. Y. | 29 |
| Skate Fastenings, | J. B. Gibbs, | Boston, | Mass. | 29 |
| Skates, | Alfred Hathaway, | Charlestown, | " | 1 |
| ——— | H. W. Warner, | Greenfield, | " | 1 |
| Skating Boots, | Pearson & Peabody, | Winchester, | " | 1 |
| Skirts,—Sides for Hoop | Henry Scheuerle, | City of | N. Y. | 1 |
| Soaps,—Castor Oil | T. D. Mathews, | St. Peter's Par. | S. C. | 1 |
| Springs for Railroad Cars, | T. F. Allen, | Dyersville, | Iowa, | 15 |
| Spoke Machines,—Mechanism | Eliakim Briggs, | South Bend, | Ind. | 1 |
| Staging,—Steamboat | A. John Bell, | Ashland, | Ky. | 22 |
| Stave Jointer, | Gabrion & Whitney, | Copenhagen, | N. Y. | 22 |
| —— Machines, | E. and B. Holmes, | Buffalo, | " | 22 |
| Steam Cylinders,—Relieving | G. W. Furman, | Brooklyn, | " | 15 |
| ——— Engines, | N. S. Bean, | Manchester, | N. H. | 15 |
| ——— | Tisdale Carpenter, | Providence, | R. I. | 29 |
| ——— | P. L. Weimer, | Lebanon, | Penna. | 29 |
| ——— Hammers, | R. R. Taylor, | Reading, | " | 1 |
| ——— Pressure Gauge, | Wm. Burnett, | Boston, | Mass. | 29 |
| Stilts, | Josee Johnson, | City of | N. Y. | 22 |
| Stove Lining, | Snider & Gorton, | Yorkville, | " | 29 |
| Stove and Air-heating Furnace, | P. J. Ackerman, | Paterson, | N. J. | 22 |
| Stoves,—Cooking | J. G. Treadwell, | Albany, | N. Y. | 22 |

| | | | | |
|---|---|---|---|---|
| Straw Cutters, | Wm. Newbury, | Clarksville, | Mo. | 1 |
| Stump Extractors, | Davis & Punchus, | Elkhart, | Ind. | 29 |
| Table Fan, | A. R. Traber, | St. Martinsville, | La. | 29 |
| Thills to Axles,—Connecting | W. H. Saunders, | Hastings, | N. Y. | 8 |
| Time Detector,—Watchman's | John Burk, | Schwenningen, | Germ'y, | 1 |
| Tire Heater, | Alfred Ingalls, | Independence, | Iowa, | 22 |
| Tobacco,—Drying | W. B. Hix, | Rome, | Ga. | 8 |
| Tomatoes,—Spirituous Liquors | Wm. Schilling, | Baltimore, | Md. | 1 |
| Tool Handles, | L. C. Rodier, | Springfield, | Mass. | 22 |
| Tools,—Polishing | T. J. Mayall, | Roxbury, | " | 22 |
| Trunk Locks, | E. L. Gaylord, | Terrysville, | Conn. | 29 |
| Tucking Gages, | G. C. Munson, | City of | N. Y. | 22 |
| Type Cases, | Thomas N. Rooker, | " | " | 1 |
| Valve Motion for St'm Engines, | J. H. Dialogue, | Camden, | N. J. | 1 |
| Valves,—Slide | Braidwood & Whiting, | Mt. Vernon, | N. Y. | 15 |
| Veneer Planer, | George Williamson, | Newark, | N. J. | 1 |
| Wagon,—Dumping | John Wilkinson, | Baltimore, | Md. | 15 |
| Watches, | A. L. Dennison, | Waltham, | Mass. | 1 |
| Washing Machine, | J. M. Bois, | Aurora, | N. Y. | 29 |
| Water Elevators, | J. M. Connel, | Newark, | Ohio, | 1 |
| —— Meters, | F. G. Johnson, | Brooklyn, | N. Y. | 1 |
| —— Wheels, | G. W. Armstrong, | Clinton, | N. C. | 29 |
| —— | Joel Harris, | New Carlisle, | Ind. | 29 |
| Wearing Apparel,—Pockets of | Fenner Darling, | N. Blackstone, | Mass. | 29 |
| Windmills, | Willis Holmes, | Macomb, | Ill. | 15 |
| —— | G. H. Reister, | Washington, | Iowa, | 15 |
| Window Sashes, | E. P. Carter, | China, | N. Y. | 8 |
| —— Stop and Fastener, | Clark Shaw, | East Aurora, | " | 29 |
| Wood-bending Machines, | Hiram McDonald, | Union Springs, | " | 22 |
| Wool,—Drawing and Twisting | J. T. Plummer, | Plainfield, | Conn. | 1 |
| Wrench, | Ezra Ripley, | Troy, | N. Y. | 1 |
| Wrenches,—Screw | L. and A. G. Coes, | Worcester, | Mass. | 8 |

ADDITIONAL IMPROVEMENTS.

| | | | | |
|---|---|---|---|---|
| Boots & Shoes,—Metallic Heels | J. V. Dinsmore, | Auburn, | Me. | 15 |
| Gate, | Jasper Johnson, | Genesee, | N. Y. | 29 |
| Refrigerator, | Wm. M. Baker, | Walpole, | Ind. | 15 |

RE-ISSUES.

| | | | | |
|---|---|---|---|---|
| Buildings,—Seats for Public | A. H. Allen, | Boston, | Mass. | 15 |
| Candles,—Moulding (2 pat's) | Willis Humiston, | Troy, | N. Y. | 22 |
| Clothes Wringer, | Elliot Dickerman, | Richmond, | Vt. | 8 |
| Gate, | Jasper Johnson, | Genesee, | N. Y. | 8 |
| Grain Cradles, | M. R. Flanders, | Parishville, | " | 8 |
| —— Separators, | J. A. Vaughn, | Cuyahoga Falls, | Ohio, | 8 |
| Guns,—Magazine | E. H. Graham, | Manchester, | N. H. | 8 |
| Harvesters, | S. and J. H. Barley, | Longwood, | Mo. | 22 |
| —— | John Gore, | Brattleboro', | Vt. | 15 |
| —— (2 pat's) | Palmer & Williams, | Brockport, | N. Y. | 1 |
| ——,—Grain and Grass | Brown & Bartlett, | Woonsocket, | R. I. | 1 |
| ——,—Grass (4 pat's) | J. S. and D. Lake, | Smith Landing, | N. J. | 1 |
| Passenger Cars,—St'm Engs. for | Robert H. Long, | Philadelphia, | Penna. | 15 |
| Presses,—Tobacco (2 pat's) | Wm. Cameron, | Petersburg, | Va. | 15 |
| —— | Lindsay & Cameron, | " | " | 15 |
| Pulp Machines, | Henry Keney and others, | Hartford, | Conn. | 1 |
| Steam Engines, (2 pat's) | F. E. Sickels, | City of | N. Y. | 1 |
| Teeth,—Porcelain | J. W. Moffitt, | Harrisburg, | Penna. | 8 |
| Threshing Machines, | D. S Wagener, | Penn Yan, | N. Y. | 29 |
| Valves of St'm Engs., (2 pat's) | F. E. Sickels, | City of | " | 1 |

## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, March* 21, 1861.]

John C. Cresson, President, in the chair.
John Agnew, Vice President.
John F. Frazer, Treasurer.
Isaac B. Garrigues, Recording Secretary. } Present.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Astronomical Society, London; la Société Industrielle de Mulhouse, and l'Ecole des Mines, Paris, France; Prof. A. Dallas Bache, Superintendent U. S. Coast Survey, Washington, D. C.; B. H. Latrobe, Esq., Baltimore, Md.; the Cooper Union, City of New York; the Board of Water Commissioners, Detroit, Michigan; the Longview Asylum for the Insane, Columbus, Ohio; the Pennsylvania Institution for the Blind, H. M. P. Birkenbine, Esq., Messrs. Merrick & Sons, Horatio Hubbell, Esq., Henry Howson, Esq., and Professors John C. Cresson and John F. Frazer, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer read his statement of the receipts and payments for the month of February.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (5) were proposed, and the candidates proposed at the last meeting (5) duly elected.

The Actuary reported that the following Standing Committees have organized by electing their Chairman, and appointing their times for meeting, viz:

| *Committee.* | *Chairman.* | *Time of Meeting.* |
|---|---|---|
| On Library, | George Erety, | 1st Tuesday evening. |
| " Exhibitions, | John E. Addicks, | 1st Thursday " |
| " Cabinet of Models, | John L. Perkins, | 2d Monday " |

Dr. Rand exhibited a specimen of fabric woven from the so-called "Fibrillia." This is prepared from flax, hemp, &c., by exposing the material to high pressure steam, and allowing it suddenly to escape into the air, by which the fibres are disintegrated and form a cotton-like mass.

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## METEOROLOGY.

For the Journal of the Franklin Institute.

*The Meteorology of Philadelphia.* By JAMES A. KIRKPATRICK, A.M.

FEBRUARY.—The month of February of this year was the warmest for the last ten years, with the exception of February, 1857, which

was about half a degree warmer. The mean temperature for the month, as will be seen by the accompanying table, was seven degrees higher than that of February, 1860, and nearly six degrees higher than the average for the last ten years.

The 28th of the month was the warmest day, its mean temperature being 56·2°. The thermometer reached its maximum (68½°) on the same day. The coldest day of the month was the 8th, the mean temperature being 8·2°. The minimum (—1°) was reached on the same day. The only time on my record besides this on which the temperature fell below zero in February, was the year 1855, when it marked one degree below, on the 7th of the month, during a heavy snow-storm. The mean temperature of the 7th of February, 1855, was 5·7°.

On the 7th of the month, a severe snow-storm occurred in Canada, and extended throughout New England and northern New York, accompanied by a heavy north-west gale. The wind storm extended from Quebec to the southern boundary of Virginia, and as far west as Buffalo. At Philadelphia, it commenced to rain at 1½ P. M., the wind from the S. S. W. At 2¼ P. M., the rain changed to snow, which fell for about fifteen minutes. At 3 P. M., the wind changed to the north-west, and became very strong. The gale continued all night, and until the afternoon of the next day, doing considerable damage.

The sudden change of temperature during this storm was very remarkable. At 7 A. M. on the 7th, the temperature was 36½°; at 2 P. M., 41°; at 9 P. M. 6°; a difference in seven hours of 35°. At 6 A. M., on the 8th, the temperature was 1° below zero; at 7, it was at zero; at 2 P. M., 10° above zero; at 9 P. M., 14½°.

On the 15th of the month, a heavy shower of rain fell, accompanied, about 2 P. M., by thunder and lightning—the first observed this year.

The temperature was below the freezing point on twelve days of the month; but it rose above that point some time during every day, except on the 8th, when the highest point attained was 16°.

The mean daily range and daily oscillation of temperature were both greater than usual.

The pressure of the atmosphere was greatest (30·485 inches) on the morning of the 9th, and least (29·308 inches) on the afternoon of the 7th. The mean pressure was greatest on the 9th, and least on the 15th of the month. The mean daily range or average of changes of pressure, was four-hundredths of an inch greater than usual.

Snow fell on only two days of the month: that is, on the 7th and 20th. The amount of rain and melted snow for the month (2·124 inches) was the smallest quantity for this month since 1857, and was half an inch less than the average for the last ten years

The force of vapor was greater, and the relative humidity less, than usual, as will appear more particularly in the following table of comparisons.

*A Comparison of some of the Meteorological Phenomena of* FEBRUARY, 1861, *with those of February, 1860, and of the same month for ten years, at Philadelphia.*

| | Feb., 1861. | Feb., 1860. | Feb., 10 years. |
|---|---|---|---|
| Thermometer.—Highest, | 68·5° | 70·0° | 70·0° |
| " Lowest, | —1·0 | 1.0 | —1·0 |
| " Daily oscillation, | 17·27 | 17·80 | 13·65 |
| " Mean daily range, | 8·90 | 8·80 | 7·46 |
| " Means at 7 A. M., | 33·86 | 27·24 | 29·22 |
| " " 2 P. M., | 45·55 | 38·07 | 38·68 |
| " " 9 P. M., | 39·14 | 31·69 | 33·55 |
| " " for the month, | 39·52 | 32·33 | 33·82 |
| Barometer.—Highest, | 30·485 in. | 30·358 in. | 30·638 in. |
| " Lowest, | 29·308 | 29·099 | 29·065 |
| " Mean daily range, | ·264 | ·209 | ·220 |
| " Means at 7 A. M., | 29·954 | 29·970 | 29·919 |
| " " 2 P. M., | 29·912 | 29·885 | 29·871 |
| " " 9 P. M., | 29·951 | 29·918 | 29·901 |
| " " for the month, | 29·939 | 29·924 | 29·897 |
| Force of Vapor.—Means at 7 A. M., | ·158 in. | ·124 in. | ·140 in. |
| " " " 2 P. M., | ·169 | ·154 | ·166 |
| " " " 9 P. M., | ·186 | ·150 | ·162 |
| Relative Humidity.—Means at 7 A. M., | 75 per ct. | 74 per ct. | 79 per ct. |
| " " " 2 P. M., | 52 | 59 | 64 |
| " " " 9 P. M., | 70 | 72 | 77 |
| Rain and melted snow, | 2·124 in. | 2·724 in. | 2·669 in. |
| No. of days on which rain or snow fell, | 9 | 8 | 10 |
| Prevailing winds, | s 77° 6′ w ·354 | N 61° 52′ w ·298 | N 72° 12′ w ·303 |

WINTER.—The winter of 1860–61 was one degree warmer than the average winter temperature for the last ten years, and more than one degree warmer than the winter of last year.

The warmest day was the 28th of February, of which the mean temperature was 56·2°. The coldest day was the 13th of January, mean temperature 7·8°. The highest degree (68½) was reached on the 28th of February, and the lowest (—1) on the 8th of the same month.

The pressure of the atmosphere was nearly two-hundredths of an inch greater than the average winter pressure for the last ten years. This increase was greater at 2 P. M. than at the other hours of observation.

The force of vapor was less at 2 P. M. and greater at 9 P. M. than usual, but the average for the winter was almost precisely the same as for the preceding winter, and but three-thousandths of an inch less than the average for ten years. The relative humidity was also remarkably near that of the preceding year, though the average for the winter was two per cent. less than the winter average for the whole time of observation.

Rain fell on thirty days to the aggregate depth of 10·045 inches, which is about half an inch above the average.

The prevailing winds during this winter came from a point about two degrees north of their direction for the winter of 1859–60; and about the same distance south of their average direction for ten years.

*A Comparison of the* WINTER *of* 1860-61, *with that of* 1859-60, *and of the same season for ten years, at Philadelphia.*

| | Winter. 1860–61. | Winter. 1859–60. | Winter. for 10 years. |
|---|---|---|---|
| Thermometer.—Highest, | 68·5° | 71·0° | 71.0° |
| " Lowest, | —1·0 | 1·0 | —5·5 |
| " Daily oscillation, | 13·69 | 15·60 | 12·53 |
| " Mean daily range, | 6·63 | 7·90 | 6·89 |
| " Means at 7 A. M., | 30·28 | 28·93 | 29·39 |
| " " 2 P. M., | 38·51 | 37·64 | 37·56 |
| " " 9 P. M., | 33·95 | 32·18 | 32·93 |
| " " for the winter, | 34·25 | 32·91 | 33·29 |
| Barometer.—Highest, | 30·526 in. | 30·399 in. | 30·704 in. |
| " Lowest, | 29·285 | 29·099 | 28·941 |
| " Mean daily range, | ·230 | ·189 | ·213 |
| " Means at 7 A. M., | 29·961 | 29·960 | 29·950 |
| " " 2 P. M., | 29·925 | 29·902 | 29·909 |
| " " 9 P. M., | 29·959 | 29·929 | 29·935 |
| " " for the winter, | 29·949 | 29·930 | 29·932 |
| Force of Vapor.—Means at 7 A. M., | ·139 in. | ·136 in. | ·138 in. |
| " " " 2 P. M., | ·151 | ·156 | ·162 |
| " " " 9 P. M., | ·155 | ·150 | ·153 |
| Relative Humidity.—Means at 7 A. M., | 78 per ct. | 77 per ct. | 79 per ct. |
| " " " 2 P. M., | 63 | 63 | 67 |
| " " " 9 P. M., | 74 | 74 | 76 |
| Rain and melted snow, | 10·045 in. | 9·535 in. | 9·646 in. |
| No. of days on which rain or snow fell, | 30 | 26 | 30 |
| Prevailing winds, | s65°37′w ·354 | s 67°50′w ·289 | s63°31′w ·308 |

*Abstract of Meteorological Observations for January,* 1861; *for the County of Philadelphia, Pennsylvania.*

PHILADELPHIA.—Lat. 39° 57′ 28″ N. Long. 75° 10′ 28″ W. Height above the sea 50 feet. Prof. J. A. KIRKPATRICK, Observer.

| 1861. Jan. | Barometer. Mean. | Barometer. Mean daily range. | Thermometer. Mean. | Thermometer. Daily oscillation. | Thermometer. Mean daily range. | Force of vapor. 2 P.M. | Relative humidity. 2 P.M. | Rain and snow. | Prevailing winds. |
|---|---|---|---|---|---|---|---|---|---|
| | Inch. | Inch. | ° | ° | ° | Inch. | Per ct. | Inch. | Direc. |
| 1 | 30·235 | ·079 | 26·3 | 19 | 7·7 | ·143 | 79 | | N W. |
| 2 | 30·046 | ·189 | 32·0 | 16 | 6·7 | ·164 | 71 | 1·278 | S W. |
| 3 | 29·673 | ·373 | 35·8 | 6 | 4·8 | ·184 | 85 | 0·025 | N N E. |
| 4 | 29·953 | ·280 | 32·5 | 7 | 3·3 | ·144 | 75 | 0·021 | N W. |
| 5 | 30·174 | ·221 | 32·0 | 13 | 3·2 | ·181 | 80 | | W. |
| 6 | 30·134 | ·086 | 35·0 | 13 | 3·0 | ·115 | 47 | | S W. |
| 7 | 29·751 | ·389 | 41·7 | 19½ | 6·7 | ·226 | 76 | 0·066 | S W. |
| 8 | 29·872 | ·142 | 41·2 | 8 | 2·8 | ·184 | 66 | | W. |
| 9 | 29·752 | ·220 | 35·2 | 6 | 6·0 | ·169 | 80 | 0·567 | S E. |
| 10 | 29·604 | ·257 | 31·8 | 8 | 3·3 | ·141 | 69 | | N E. |
| 11 | 29·945 | ·341 | 24·7 | 13 | 10·2 | ·101 | 86 | 0·048 | N W. |
| 12 | 29·964 | ·178 | 26·3 | 17 | 8·0 | ·111 | 76 | 0·039 | N W. |
| 13 | 30·424 | ·460 | 7·8 | 11 | 12·5 | ·049 | 69 | | N N W |
| 14 | 30·190 | ·264 | 22·5 | 22 | 14·7 | ·111 | 87 | 0·404 | N N E. |
| 15 | 29·848 | ·312 | 34·3 | 6½ | 11·8 | ·184 | 85 | 0·476 | N N W |
| 16 | 29·558 | ·290 | 38·2 | 6 | 3·8 | ·225 | 91 | | (var.) |
| 17 | 29·902 | ·344 | 41·5 | 13 | 3·3 | ·196 | 53 | | W. |
| 18 | 29·920 | ·218 | 25·7 | 8 | 6·2 | ·190 | 90 | 0·270 | S E. |
| 19 | 29·713 | ·226 | 39·3 | 17½ | 4·0 | ·146 | 44 | | (var.) |
| 20 | 29·869 | ·157 | 34·6 | 12 | 6·8 | ·094 | 40 | | W. |
| 21 | 30·081 | ·212 | 30·7 | 12 | 3·8 | ·095 | 45 | | W N W |
| 22 | 30·393 | ·315 | 20·7 | 11½ | 6·0 | ·129 | 78 | | N W. |
| 23 | 30·483 | ·095 | 25·2 | 11 | 1·2 | ·117 | 72 | | (var.) |
| 24 | 29·967 | ·516 | 34·2 | 14 | 9·3 | ·207 | 90 | 0·917 | N E. |
| 25 | 30·089 | ·188 | 30·0 | 4½ | 3·2 | ·142 | 62 | | W N W |
| 26 | 30·048 | ·071 | 28·0 | 9 | 8·0 | ·153 | 100 | 0·510 | N W. |
| 27 | 29·989 | ·060 | 20·2 | 12 | 3·8 | ·145 | 84 | | N W. |
| 28 | 29·964 | ·058 | 20·3 | 12½ | 3·2 | ·138 | 70 | | W. |
| 29 | 29·781 | ·183 | 34·8 | 19 | 5·6 | ·151 | 60 | | S W. |
| 30 | 29·867 | ·241 | 27·8 | 12 | 9·7 | ·087 | 58 | | W N W |
| 31 | 30·004 | ·160 | 23·0 | 11 | 4·8 | ·085 | 58 | | W. |
| Means | 29·971 | ·229 | 31·0 | 11·4 | 6·0 | ·144 | 72 | 4·020 | s65°w |

*Abstract of Meteorological Observations for January,* 1861; *made in Franklin, Somerset, Bradford, and Centre Counties,*

*Abstract of Meteorological Observations for January, 1861; made in Franklin, Somerset, Bradford, and Centre Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.*

| | Chambersburg, Franklin Co. Lat. 39° 58′ N. Long. 77° 45′ W. Height 618 ft. Wm. Heyser, Jr., Observer. | | | | | | | Somerset, Somerset Co. Lat. 40° N. Long. 79° 3′ W. Height 2195 feet. Geo. Mowry, Observer. | | | | | | | Towanda, Bradford Co. 41° 47′ N. 76° 34′ W. Height, ab't 840 ft. S. J. Coffin, Obs. | | | | Fleming, Centre Co. 40° 55′ N. 77° 53′ W. Ht., 780 feet. S. Brugger, Obs. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1861. Jan. | Barom Mean. | Thermom. Mean. | Thermom. Mean daily range. | Force of vapor. 2 P. M. | Relative humidity. 2 P. M. | Rain and snow. | Prevail'g winds. | Barom Mean. | Thermom. Mean. | Thermom. Mean daily range. | Force of vapor. 2 P. M. | Relative humidity. 2 P. M | Rain and snow. | Prevail'g winds. | Barom. Mean. | Thermom. Mean. | Thermom. Mean daily range. | Prevail'g winds. | Thermom. Mean. | Thermom. Mean daily range. | Rain and snow. | Prevail'g winds. |
| | Inch. | ° | ° | Inch. | Per ct. | Inch. | Direc. | Inch. | ° | ° | Inch. | Per ct. | Inch. | Direc. | Inch. | ° | ° | Direc. | ° | ° | Inch. | Direc. |
| 1 | 29·599 | 13·0 | 9·0 | ·123 | 90 | | W. | 27·879 | 27·7 | 8·7 | ·129 | 58 | | W S W | | 29.7 | | N W. | 11·0 | 4·3 | | W. |
| 2 | 29·427 | 26·0 | 13·0 | ·186 | 81 | 0·622 | (var.) | 27 681 | 38·7 | 11·0 | ·185 | 51 | 0·252 | W S W | 29·077 | 37·3 | 7·7 | (var.) | 26·0 | 15·0 | | E. |
| ☾ 3 | 29·138 | 36·0 | 10·0 | ·203 | 82 | | N E. | 27·461 | 35·3 | 8·0 | ·177 | 66 | | W. | 28,887 | 27·3 | 12·0 | (var.) | 35·3 | 9·3 | } 0·200 | E. |
| 4 | 29·375 | 31·7 | 6·3 | ·067 | 34 | | W. | 27.631 | 25·0 | 10·3 | ·154 | 87 | 0·047 | W. | 29·050 | 24·7 | 4·0 | N W. | 27·7 | 7·7 | | W. |
| 5 | 29·609 | 29·7 | 7·3 | ·162 | 80 | | W. | 27·846 | 24·7 | 3·7 | ·147 | 78 | | W. | 29·230 | 26·0 | 3·3 | N. | 24·3 | 4·7 | | W. |
| 6 | 29·533 | 29·0 | 6·7 | ·142 | 70 | } 0·233 | E. | 27·746 | 33·0 | 10·3 | ·177 | 66 | 0·220 | W S W | 29·163 | 32·0 | 6·0 | (var.) | 28·3 | 14·0 | | W. |
| 7 | 29·173 | 40·7 | 11·7 | ·195 | 68 | | (var.) | 27·458 | 44·0 | 11·0 | ·242 | 74 | | W S W | 28·790 | 45·7 | 13·7 | S. | 35·0 | 9·3 | 0·100 | E. |
| 8 | 29·317 | 38·3 | 1·7 | ·126 | 49 | | W. | 27·630 | 31·3 | 12·7 | ·140 | 78 | | W N W | 29·013 | 30·0 | 15·7 | N. | 34·3 | 1·3 | | N W. |
| 9 | 29·159 | 35·3 | 3·0 | ·157 | 71 | 0·300 | (var.) | 27·450 | 32·3 | 1·0 | ·196 | 100 | 0·091 | ? | 28·843 | 32·3 | 3·7 | (var.) | 35·0 | 2·7 | 0·100 | E. |
| ● 10 | 29·064 | 30·0 | 5·3 | ·129 | 61 | | W. | 27·404 | 22·7 | 9·7 | ·122 | 86 | 0·279 | (var.) | 28·693 | 25·3 | 8·3 | W. | 23·0 | 12·0 | | W. |
| 11 | 29·287 | 18·7 | 11·3 | ·101 | 86 | 0·200 | (var.) | 27·540 | 23·7 | 12·3 | ·162 | 84 | 0·190 | S W. | 28·953 | 16·0 | 11·3 | N. | 16·0 | 10·3 | } 0·500 | W. |
| 12 | 29·320 | 24·7 | 9·3 | ·085 | 43 | | W. | 27·586 | 29·3 | 8·3 | ·108 | 65 | 0·080 | (var.) | 29·080 | 9·7 | 12·3 | N W. | 17·7 | 7·7 | | (var.) |
| 13 | 29·804 | 5·3 | 19·3 | ·040 | 58 | | E. | 27·925 | 11·0 | 17·7 | ·074 | 60 | | (var.) | 29·477 | 2·3 | 10·0 | (var.) | —6·0 | 23·7 | | W. |
| 14 | 29·539 | 19·0 | 13 7 | ·085 | 72 | } 0·836 | (var.) | 27·730 | 30·7 | 19·3 | ·185 | 86 | 0·362 | S. | 29·197 | 21·7 | 19·3 | (var.) | 16·7 | 22·7 | 0·620 | E. |
| 15 | 29·223 | 33·0 | 14·0 | ·149 | 70 | | E. | 27 531 | 41·0 | 10·3 | ·275 | 92 | 0·456 | ? | 28·937 | 32·0 | 10·3 | (var.) | 32·3 | 15·7 | } 0·485 | E. |
| 16 | 28·971 | 38·7 | 5·7 | ·181 | 73 | | W. | 27·283 | 37·7 | 4·0 | ·262 | 84 | 0·083 | (var.) | 28·603 | 39·3 | 7·3 | (var.) | 37·3 | 7·7 | | W. |
| 17 | 29·382 | 37·0 | 3·0 | ·144 | 63 | | W. | 27·697 | 29·3 | 8·3 | ·127 | 76 | | W. | 28·990 | 36·7 | 2·7 | S. | 36 7 | 6·7 | | N W. |
| ☽ 18 | 29·272 | 34·0 | 3·0 | ·142 | 70 | 0·195 | E. | 27·548 | 32·3 | 4·3 | ·154 | 84 | | W S W | 28·940 | 33·3 | 5·3 | S. | 35·3 | 2·7 | 0·100 | E. |
| 19 | 29·101 | 39·0 | 5·0 | ·129 | 45 | | W. | 27 514 | 34·7 | 6·3 | ·155 | 58 | | W. | 28·777 | 37·0 | 5·0 | (var.) | 34·0 | 2·0 | | N W. |
| 20 | 29·322 | 32·0 | 7·0 | ·157 | 71 | | W. | 27·674 | 25·3 | 9·3 | ·075 | 43 | | W. | 28·937 | 28·0 | 5·7 | W. | 26·0 | 8·0 | | N W. |
| 21 | 29·369 | 30·7 | 2·0 | ·173 | 73 | | W. | 27·844 | 21·7 | 3·7 | ·109 | 69 | | (var.) | 29·190 | 22·0 | 6·0 | N W. | 20·7 | 5·3 | | W. |
| 22 | 29·826 | 24·3 | 5·3 | ·049 | 25 | | W. | 28·069 | 17·3 | 5·7 | ·084 | 60 | | N W. | 29·530 | 14·7 | 7·3 | N W. | 13·3 | 7·3 | | W. |
| 23 | 29·875 | 25·0 | 2·3 | ·078 | 46 | | E. | 28·050 | 22·7 | 5·3 | ·083 | 52 | } 0·468 | S E. | 29·607 | 16·0 | 6·0 | (var.) | 18·3 | 5·7 | | E. |
| 24 | 29·359 | 30·0 | 5·0 | ·047 | 25 | 0·400 | E. | 27·639 | 31·3 | 8·7 | ·183 | 90 | | (var.) | 29·063 | | | S E. | 32·0 | 13·7 | 0·650 | E. |
| 25 | 29·453 | 33·3 | 4·7 | ·136 | 62 | | W. | 27·727 | 27·3 | 5·3 | ·116 | 53 | | W. | 29·077 | 31·7 | | N W. | 26·3 | 7·0 | | W. |
| ○ 26 | 29·541 | 25·3 | 8·0 | ·100 | 66 | 0·500 | E. | 27·721 | 24·0 | 4·0 | ·104 | 69 | 0·224 | E. | 29·147 | 21·7 | 10·0 | S W. | 20·0 | 6·3 | 0·050 | E. |
| 27 | 29·402 | 17·3 | 10·7 | ·108 | 59 | | N E. | 27·634 | 29 3 | 7·3 | ·144 | 63 | | W. | 29·010 | 22·0 | 1·7 | (var.) | 20 0 | 8·7 | | W. |
| 28 | 29 345 | 23·7 | 6·3 | ·085 | 43 | | E. | 27·668 | 24·3 | 5·0 | ·134 | 77 | 0·045 | (var.) | 29·000 | 24·0 | 6·0 | N W. | 19·7 | 14·3 | | N W. |
| 29 | 29·128 | 35·0 | 11·3 | ·123 | 54 | | (var.) | 27·472 | 40·7 | 16·3 | ·185 | 58 | | W. | 28·757 | 35·0 | 11·0 | S W. | 30·0 | 11·7 | | W. |
| 30 | 29·340 | 23·3 | 11·7 | ·061 | 41 | | W. | 27·655 | 16·0 | 24·7 | ·096 | 85 | | W. | 28·953 | 20·3 | 11·3 | N W. | 16·0 | 14·0 | 0·100 | N W. |
| 31 | 29·423 | 19·0 | 5·0 | ·066 | 43 | | (var.) | 27·663 | 17·3 | 7·3 | ·140 | 88 | | W. | 29·040 | 22·0 | 1·7 | N W. | 16·7 | 4·7 | | N W. |
| Means | 29·376 | 29·8 | 7·7 | ·120 | 60 | 3·286 | N 54° W | 27·657 | 28·3 | 9·0 | ·149 | 72 | 2·797 | S 65° W | 29·037 | 26·5 | 8·0 | N 66° W | 24·4 | 9·2 | 2·905 | N 65° W |